Final Report

Assessing fishing seasons for red-leg banana prawns in the Joseph Bonaparte Gulf and future directions for collaborative research for NPF Industry Pty Ltd.

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2008/102	**Assessing fishing seasons for red-leg banana prawns in the Joseph Bonaparte Gulf and future directions for collaborative research for NPF Industry Pty Ltd.**

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OBJECTIVES:

1. Collect and review all existing data and research results for the Joseph Bonaparte Gulf red-leg banana prawn stock,
2. Develop a preliminary assessment of the Joseph Bonaparte Gulf red-leg banana prawn stock focusing on how yields, catch rates and production costs might be optimized in the medium and long term.
3. In the context of that preliminary assessment conduct an initial sensitivity analysis of the fishery to identify critical gaps in the knowledge needed to optimize red-leg banana prawn production in the Joseph Bonaparte Gulf, and
4. Identify data that would be most valuable for industry to collect
5. Present these analyses and findings to an industry meeting to develop a long term approach to monitoring and optimising the value of red-leg banana prawns from the Joseph Bonaparte Gulf.

Non-technical Summary:

OUTCOMES ACHIEVED TO DATE

The immediate outcome from this project was a robust science based discussion of the future management of the JBG which suggested directions for the further analysis of JBG data to support industry's developing interest in defining optimal levels for fishing effort for the JBG. The discussion demonstrated the value industry members place upon being informed by basic data and simple relevant analyses. By invitation, the project team will develop with industry, a cost-effective long-term strategy for collaborating with independent researchers and analysts to improve industry's application of data to developing management policies for optimizing the value of NPF resources. An outcome of this project is agreement to develop a collaboration, that will probably be based around a studentship or post-doctoral research fellow that could work with industry to assemble data-sets and improve models of the main component stocks of the NPF.

To enhance its profitability, NPF Industry Pty Ltd needs to develop its capacity to gather key stock status data for each of its stocks so that simple bio-economic models can be developed and used to assess and potentially optimize the value of component NPF stocks. The NPF Industry Pty Ltd needs its discussion of management policy for localized stocks to be based on sound scientific data. This project started developing the capacity of NPF Industry Pty Ltd to support science based discussions of management by synthesizing the existing data for the red-leg banana prawn (*Penaeus indicus*) stock in the Joseph Bonaparte Gulf (JBG) and developing initial, simple bio-economic models for the stock.

The immediate need addressed by this project was to provide a scientific basis for discussions about the timing and duration of the 2010 JBG season. This was provided through discussions with Industry in Brisbane, in February 2010. Two very simple preliminary bio-economic models were developed, each using different sources of data; a fisheries model based on catch and effort data reported from the fishery, and a Value-Per-Recruit model based on biological data. The two alternative modeling approaches used differing sources of data; fisheries data in the Fisheries model, and biological data in the Value-Per-Recruit model, but both describe the same phenomena and suggest a similar order of magnitude in the differences between the alternative scenarios for opening the fishing seasons. The first bio-economic model, the Fishery model, describes the dynamic as experienced with, and recorded in the JBG's catch and effort data. While the Value-Per-Recruit model, used scientifically measured biological parameters collected mainly from previous FRDC funded research projects, to model the underlying biological mechanism behind some of the trends described by the Fisheries model. The agreement between the differing models and data sources suggests that the broad findings of this initial analysis; that profits from the JGB will be maximized at moderate effort levels and fishing only in the second season (i.e. after season date), are robust. Taken together, these analyses clearly suggest that a strategy of moderate fishing pressure in the second season will produce superior outcomes in terms of profitability and conserving egg production. They suggest that on average, such strategies might increase aggregate profits from the fishery by 50 to 100% above the alternative fishing scenarios involving fishing both the early and late seasons. Both the timing of the fishing season and the intensity of fishing can contribute to determining the size and value of the prawns taken. Heavy fishing will produce smaller prawns and light fishing larger prawns. Fishing intensity alone determines the cost of fishing. The Value-Per-Recruit model shows that confining fishing to the second season will conserve greater levels of spawning activity and produce a larger more valuable catch of prawns. On the production side, but not factored into the analysis, prawns produced during the second season and caught late in this season only require storage for a short time prior to the main pre-Christmas sales period.

The limitation of this preliminary Value-Per-Recruit model is the assumption of a single cohort. The evidence gathered by this study is that recruitment occurs over months, although the data showing this have poor coverage over summer. A broad pulse of recruitment continuing through much of the year might suggest that the timing of the seasons in the JBG, may not be only, or best way of managing so that larger prawns are produced, and fishing pressure on small cohorts reduced. Interviews conducted with JBG fishermen clearly identified that reviewing the shallower boundaries of current JBG fishing ground, and increasing the area of shallow nursery and juvenile grounds closed to fishing, might achieve similar ends.

The output of this project in the form of a written report circulated before the meeting, formal presentations and follow-up discussions, around the meeting of NPF Industry Pty Ltd in Brisbane, February 2010. These sources of information provided the basis for industry to discuss future management of the JBG in the context of the available scientific information. The members of NPF Industry Pty Ltd benefited from this project by having the available information about the JBG synthesized, analyzed and presented to provide context for their discussion. Industry members expressed their appreciation for having information about the JBG made accessible in simple time series trends and easily conceptualized models.

This project facilitated discussion as to how NPF Industry Pty Ltd could cost-effectively continue to develop its capacity to apply existing data and science to the development of management policy. The NPF Industry Pty Ltd members expressed a strong aversion to developing expensive survey systems. Student or post-doctoral projects through a university like Murdoch University could be used to work cost-effectively with industry on biological studies, collecting samples locally from NPF catches transported to Perth for processing. These studies could refine estimates of prawn growth and movement across the various fishing grounds, allowing more sophisticated bio-economic models of the main NPF stocks to be developed. Having developed models for several component stocks, a Harvest Strategy Evaluation framework, could then be developed to analyse the differential in opportunity costs by fleets between component areas of the NPF, and the way this drives fishing patterns through the year, and the overall profitability of the NPF in aggregate.

KEYWORDS: Value-Per-Recruit, costs of fishing, trawl fishing, *Penaeus indicus*

Acknowledgments

We are grateful to Mr David Vance and Dr Eva Plaganyi of CSIRO, Cleveland for providing data and assisting in locating the original results of Dr Rick Buckworth's studies which were retrieved from CSIRO archives. We are also grateful to the various JBG skippers who gave so freely of the knowledge and experience. Thanks to Mr Rob Kenyon, CSIRO, for his organization of the NPF RAG meetings and thanks to the NPF Industry Pty Ltd for robust discussions during meetings.

Background

Since the recent Commonwealth funded buy-back, the NPF has effectively consolidated down to 19 shareholders operating about 50 fishing vessels, sharing a turnover of approximately $60-70 million per annum based on fishing 9 main species, each with a number of regional stocks. In this context the NPF could be thought of as being a company of shareholders sharing the management and harvesting of some 20-30 stocks each of which could be thought of as an extensive farm for wild prawns. While fishermen and fishing companies have traditionally competed fiercely with each for fishing grounds and for fish within fishing grounds, in today's economic environment it makes no sense for the shareholders of the same company (NPF Pty Ltd) to compete heavily against each other when it results in increased harvesting costs and lower aggregate returns. To emphasise this point, consider a publicly listed company set up to run a land based prawn farm and which had an equivalent turnover of $60-70 million. It is inconceivable that its board of directors would tolerate its employees actively working against each other to the detriment of the value of the harvest and its cost structures. However, because the NPF is a wild stock fishery this situation is considered normal.

The smart way of doing business would be for the shareholders to work together for mutual benefit with the aim of reducing operational costs and increasing returns from the resource. The shareholders should be developing ways of co-operating together to optimize the productivity of each stock so that the value of the prawns they each produce is maximized and harvesting costs minimized. In this way the aggregate profitability could be increased to the mutual benefit of all shareholders. While probably not the optimal model for the NPF, the South Australian Spencer Gulf fishery for western king prawns (*P. latisulcatus*) provides a classic example of how a prawn industry can work together to achieve the twin aims of optimizing the value of its harvest and reducing costs. That industry undertakes its own system of surveys in order to conduct real-time assessment and management to enhance its performance in terms of economics and sustainability.

To enhance its profitability NPF Industry Pty Ltd needs to start developing capacities like those of the Spencer Gulf Prawn fishery, and go on to apply them to each of the main NPF stocks. This project is a start to developing the capacity of NPF Pty Ltd to apply scientific analysis and discussion to its management of component NPF resources. If this long-term aim is to become reality a core capacity required by NPF Pty Ltd is to gather key stock status data for each stock, and analyse within season trends in prawn biomass so that bio-economic models can be developed and used to assess and optimize production from each stock. This project started developing these capacities by developing simple bio-economic models using existing data for red-leg banana prawn (*P. indicus*) stock in the Joseph Bonaparte Gulf (JBG).

The Red-leg Banana Prawn Fishery in Joseph Bonaparte Gulf

The main species taken in the JBG is the red-leg banana prawn (*P. indicus*), which is one of the lesser known species in the NPF and its management has until recently, been determined mainly as a "byproduct" of management measures for other species in the NPF. In recent years, the JBG has been fished with the two seasonal openings in the NPF, i.e. from April to June and August to November. The first season has been kept closed in the JBG since 2007, meaning that fishing is now only allowed from August until November. The main reason the current closures were implemented in the JBG was to see if the change would allow greater numbers of larger and more valuable prawns to be caught in the JBG but no clear objectives or performance measures were established and no system was put in place to evaluate the actual impact of the single late open season.

Large prawns are more valuable than small prawns, but large catches of smaller prawns may still have more value than smaller catches of large prawns. Besides the value of the catch, the cost of harvesting, timing relative to market demand, and cost of storage, must all also be considered in evaluating the costs and benefits of management changes.

The long-term average catch of red-leg prawns is estimated to have been about 680 t per annum during the 1980s and 570 t per annum during the 1990s (Loneragan et al. 2002). By comparison, the red-leg catch was about 200 t in 2007 and 2008, along with 150-200 t of banana prawns (*P. merguensis*). The number of days being fished in the JBG is clearly much lower (254 days in 2006 and 206 days in 2007) compared to 1,680 boat days per year during the 1980s and 1,082 during the 1990s when the major part of the fishery took place in May, i.e. during the first season. It is clear that in the most recent seasons, poor weather conditions during August and the cost of operating in the remote JBG has delayed the start of fishing until mid- to late- September, limiting the level of effort that can be applied in this region. These conditions may be relatively normal and if so should be factored into a fishing plan for the JBG. It is also possible that with fewer days being fished and despite a smaller total catch, if the prawns being caught are significantly bigger, industry may have benefited from the change in season. However, if the prawns are no bigger now, the lower catches might suggest the management changes have been to the detriment of NPF Industry Pty Ltd.

Because no data have been gathered, it is not clear whether or not the change in season has increased the size and value of red-leg prawns being caught. Anecdotal reports since the change apparently were giving no clear indication of a change in the size of the prawns in the catch, so it was not possibly to scientifically evaluate whether the management changes has succeeded in its aim of enhancing the value of the JGB resource, or has in fact reduced its value to NPF Pty Ltd. If the size of prawns has not changed, allowing fishing in both seasons might allow a larger more valuable catch to be taken, potentially at lower costs during the better sea conditions of May. The current arrangement might even have been increasing the risk of recruitment overfishing by focusing on a relatively small biomass of larger prawns close to the peak of their spawning effectiveness. There is increasing appreciation that isolated prawn stocks are particularly prone to recruitment overfishing and anecdotal information suggests JBG catches have been declining.

Little targeted research has been carried out on red-leg banana prawn (*P. indicus*). In recent years only rudimentary catch and effort, and commercial grading data have been collected and even this has not yet been subject to systematic analysis. In these circumstances it could be argued that recent trends support five plausible explanations with differing management implications:

1. The late season has optimized the value of production.
2. Value is being forfeited because the season is too late and the annual peak in biomass is being missed.
3. Value is being forfeited because poor weather late in the year and other fishing commitments prevent enough boats days to fish prawns effectively in the JBG.
4. The late season effectively intensifies fishing on the aggregated spawning biomass increasing the risk of recruitment over-fishing.
5. Natural variability has been producing lower catches than normal

This proposal was initiated by Messrs Martin Excel, David Carter and Andrew Pendergrast, of Austral Fisheries who began informal discussions with Prof. Neil Loneragan and Dr Jeremy Prince in late 2008. These discussions were formalized into a discussion paper prepared by this group and presented to the NPF Industry Pty Ltd in February 2009, who supported proceeding with the preparation of this TRF proposal.

Need

The NPF Industry Pty Ltd needs to base its discussion of management in the JBG, and other localized stocks, on sound scientific data and analysis. The immediate need addressed by this project was to provide a scientific basis for discussions about the 2010 JBG season, which eventually occurred at a meeting with NPF Industry in Brisbane, during February 2010.

The medium term need is for the NPF Industry Pty Ltd to begin developing its capacity to collect, collate and use its basic data to intelligently develop sound science based approaches to optimizing the value of its principle stocks.

Objectives

1. Collect and review all existing data and research results for the JBG red-leg banana prawn stock,
2. Develop a preliminary assessment of the JBG red-leg banana prawn stock focusing on how yields, catch rates and production costs might be optimized in the medium and long term.
3. In the context of that preliminary assessment, conduct an initial sensitivity analysis of the fishery to identify critical gaps in the knowledge needed to optimize red-leg banana prawn production in the JBG

4. Identify data that would be most valuable for industry to collect, and
5. Present these analyses and findings to an industry meeting to develop a long-term approach to monitoring and optimising the value of red-leg banana prawns from the JBG.

Methods

Synthesis

Work on the project began in September 2009 before the contract was signed. The first phase of the project involved collecting and reviewing the existing data and research results for the JBG red-leg banana prawn stock.

Compared with other species of prawns in the NPF, little research has been carried out on red-leg banana prawns. In the 1980s NT fisheries completed some studies on length composition, sex ratios and size at maturity, which were never published. Length frequencies and data on the maturity of red-leg banana prawns were collected by Mr Rick Buckworth of NT Fisheries and analysed to estimate growth and reproduction parameters, and the seasonal pattern of recruitment to the fishery. Later studies concluded these initial estimates of growth were unreliable and that growth was better estimated from the literature for *P. merguiensis*. The original results of Buckworth's studies were retrieved from the archives of CSIRO, Cleveland and reviewed during this study.

A feasibility study of tagging and per-recruit modeling was completed by Loneragan et al. (1997) the results of which were extended into an FRDC funded study on growth, mortality, movements and nursery habitats which was completed in 2000 (Loneragan et al. 2002, FRDC 97/105).

All these sets of data suggest a seasonal pattern of recruitment, with most prawns recruiting to the fishery between February and April. However, no length frequency data are available for the months between December and February.

In recent years, the major fishing companies involved in NPF Industry Pty Ltd have been recording data on the graded sizes of prawns caught in the JBG. This project investigated the potential for using these data to compare grade compositions between the first and second seasons of the year. However, it was found that most companies do not retain the grading data for more than 1-3 years, and in this period there had only been late openings. Unfortunately no commercial grading data could be found from earlier years that would allow size comparisons to made between the early and late seasons within a year. Data on size distributions in both seasons and during the long end of year closure would be valuable to the industry.

Catch and effort data are available from the NPF logbook data but some degree of interpolation is needed in analyzing these data because the main catch of red-leg banana prawn (*P. indicus*) in the JBG is not distinguished from minor catch of white banana prawn (*P. merguiensis*). Distributional data collected by Loneragan et al. (2002) now provide some basis for distinguishing trends of these two species in the JBG fishery.

Consultation and Development of the Analysis

Phone and one-on-one interviews were conducted informally initially with representatives of the principal NPF companies most involved with the JBG that were nominated to me by the executive of NPF Industry Pty Ltd. As part of the interviews these members of NPF Industry Pty Ltd were asked to supply contact details for the best prawn skippers considered to have the most experience with fishing in the JBG. Some 7 skippers were then followed up with phone, and with one-on-one interviews so that their knowledge of, and experience with, the JBG resource could be synthesized and applied to the analysis.

During this time an initial analysis of the JBG catch and effort data was undertaken using an extraction of NPFlogs data supplied by Mr Bill Venables Cleveland, CSIRO in 2005. The underlying patterns in the data 1980-2003 were described. Two simple bio-economic models were then developed. The first preliminary bio-economic model is based on the relationship between catch and effort observed in the fishery, as estimated from using the logbook data. The second, a Value-Per-Recruit model, is based on scientific estimations of growth, survival and catchability of red-leg prawns in the JBG as estimated by previous FRDC funded studies conducted by CSIRO. Both models use the same simple cost of catching and price model developed using cost and pricing data provided by Newfish in early 2009.

Initial results of these simple models were presented to the NPF Resource Assessment Group for discussion on 16-17 November 2009. The models were then revised following the feedback from this meeting and the most recent data (2004–2008) were supplied by Ms Eva Plaganyi Cleveland, CSIRO, from a second extraction and added to the original data set. A draft report was prepared on the results of analyses conducted with both models. The draft report on the analysis was presented to the meeting of the NPF Industry Pty Ltd preceding NORMAC on 18 & 19 February 2010. The report engendered much discussion by industry members as they discussed arrangements for fishing the JBG in 2010, and considerable positive comment in support of applying science and basic analysis to the issue of the opening time and length of season in the JBG.

A limited amount of further analysis was conducted after the February 2010 meeting in response to comments and queries these are presented in this report; as a distinct section of the results.

Modelling

First Bio-economic Model – The Fisheries Model

This first bio-economic model developed combines the fishery and economic models outlined above to estimate the expected catch and costs expected across a broad range of fishing effort with the aim of identifying optimal fishing levels and maximal levels of profit for the JBG fishery in aggregate.

In this model the Beverton & Holt (1957) relationship:

$$\text{Annual Catch} = \text{Average Recruitment} \times (1 - e^{(-A \times \text{Annual Effort})})$$

Was derived from fitting to the nominal annual total catch and effort for each year in the historic time series (1980–2008) and used to estimate the catch and thus catch rate expected on average for each level of fishing effort. These estimates of catch, catch rate and effort have then been applied to the cost of catching model, described below, to estimate the aggregate level of annual profit expected from each level of fishing effort.

Second Bio-economic Model – Value-Per-Recruit (VPR) Model

The second model developed by this project is a Value-Per-Recruit modeling (VPR) which instead of using the fisheries data, uses research data on the basic biological parameters of red-legs from JBG. This VPR model combines estimates of growth and mortality within a classic Yield-Per-Recruit model which tracks the biomass of a cohort with estimates of prawn value by size category to estimate the value of a cohort at each age and size as it grows through the fishery. The basis of this modeling approach is to assume a single age (week) class of prawns with an arbitrary abundance, which was scaled to support catches similar to that observed in the fishery, and then compute their survival, length and weight each week of their life cycle as they grow and are fished by the fishery. It should be noted that this analysis is not analyzing data from the fishery, but rather predicting relative trends and relationships using data provided by biological studies conducted in the JBG.

The absolute values contained in the model's output should be interpreted with caution and not over-interpreted. The strength of this type of analysis is in using the best sciences to define the nature, strength and magnitude of the relative relationships at play in the fishery, rather than accurately predicting the absolute level of profit from the fishery.

The biological parameters used to describe the weekly growth and survival of prawns through a 52 weeks life cycle are approximately those used by Plaganyi et al. (2009), who in turn drew them from Loneragan et al. (2002). The bio-economic part of the analysis used to describe the value of the cohort to the fishery through its life cycle is the same cost of catching model described above.

Two, parameters in this model were 'tuned' (adjusted or set) with the intention of harmonizing the values estimated by the model so that for illustrative purposes they were similar to those observed in the JBG, but there has been no fitting to data. The main tuning factor in this analysis is the number of recruits assumed for week zero, which together with the catchability parameter 'q', determine weekly catches and catch rates. These two parameters were tuned to reproduce weekly catches and catch rates similar to those recorded in the JBG while maintaining a value for catchability close to that estimated by Loneragan et al. (2002) through tagging studies. In structuring the model this way, the output is intended to be realistic, but never the less, the scenarios produced should not be interpreted as providing accurate predictions of any absolute index within any particular modeled scenario. The value of this type of analysis is in using the best data and science to define the nature, strength and magnitude of the relative relationships at play in the fishery.

Assumptions about Recruitment

It should be noted again here that the VPR model over-simplifies the entire fishery, describing it simply as the weekly progression of one cohort produced during just one week and progressing synchronously through a 52 week life-cycle. The reality is that many weekly cohorts enter the fishery and the pattern of recruitment through the year remains a major uncertainty for the fishery. Recruitment and biomass vary from year to year; none of this complexity is captured by this preliminary model.

Loneragan et al. (1997) looked at all the available scientific data, including Buckworth's and concluded that a lack of sampling during December to February, and several other months, left critical holes in the data. However they still concluded it was safe to assume a broad seasonal pulse of recruitment to the fishery peaking in March each year, and Plaganyi et al. (2009) has used this as the starting assumption in developing a JBG assessment. Having reviewed Buckworth's data again, we concur and support this earlier judgment of the data available. This scientific conclusion was supported by all the fishers interviewed during the course of this project, and most of the company people as well, however there are a few strong voices to the contrary, maintaining that recruitment is continuous all year round. It may well be that recruitment in some years maybe almost continuous through summer and autumn, but that a seasonal pulse will still dominate the dynamics of the fishery. Support for this view comes from analysis of seasonal CPUE trends (see below).

Model Structure

This model incorporates the standard relationships and describes growth and survival of a single female cohort in weekly time steps. Females and males grow at different rates with females becoming larger than males. For simplicity this model assumes the biomass is a female biomass and female growth parameters are used:

Growth:

Growth in length is described as a function of age and length using the Von Bertalanffy growth curve.

Length at Age $_{(t)}$ = Average Maximum Length x $(1 - e^{-k*(age-t_0)})$

Where the Average Maximum Length or $L_{infinity}$ (49.6 mm), the growth coefficient (k) (0.053) and the size (-0.34) at time zero (t_0) have been estimated for females in JBG through tagging by Loneragan et al. (2002).

The Length and Weight relationship that converts the carapace length (CL) of a prawn in each age class to weight is also provided by Loneragan et al. (2002):

Female Weight (g) = 0.000889 CL (mm) $^{2.914}$

Survival:

From their tagging studies, Loneragan et al. (2002) also derived a range of estimates of weekly rates of natural mortality (*M* = 0.032–0.076). This study followed Plagany et al. (2009) using an assumed *M* of 0.05. So that in the absence of fishing mortality (*F*):

Number at Time$_{(t)}$ = Number at Time$_{(t-1)}$ x $e^{(1-M)}$

The estimated level of Natural Mortality (*M*) used is relatively low for a banana prawn and this obviously has a large influence on the results of this study, favoring leaving the prawns longer to grow and breed. Due to the small scale of the TRF project there was no sensitivity testing around this value of Natural Mortality (*M*), but the evidence to support the comparatively low *M* for a banana prawn is relatively strong. Firstly there is the evidence of Loneragan et al. (2002) based on the survival of tagged prawns. Secondly, there is the evidence from the early JBG fishery of the third peak in aggregation over December – January when prawns would be expected to be around 12 months old. Significant survival through to 12 months of age in a lightly fished fishery is consistent with the estimate of *M* derived by tagging (Loneragan et al. 2002).

Catchability (q):

From their tagging studies Loneragan et al. (2002) also derived a range of estimates of catchability (*q* weekly) 0.0001–0.0006. This model has been tuned with an estimate of *q* = 0.002 applied per boat day within a given week.

In this model ,the rate of fishing mortality (*F*) is the product of the amount of effort (boat days), and catchability '*q*' which is the proportion of the population removed by each days fishing.

$F = q$ x Effort (boat days)

Modelling Fishing Mortality:

Within the model the cohort is subject to fishing mortality (*F*) within each weekly time set which is in addition to the weekly rate of natural mortality (*M*). So that when the fishery is operating:

Number at $\text{time}_{(t)}$ = Number at $\text{time}_{(t-1)}$ x $e^{(1-(M+F))}$

In this model ,fishing mortality was only applied to each cohort within the two peak seasons of catchability described by Figure 2, weeks 14–24 and 31-50. Effort (boat days) was applied within the weekly time steps during the two seasons, to produce different scenarios corresponding to combinations of openings and fishing intensity. In the scenarios analysed effort was distributed evenly across the weeks in each season.

The *F* applied in each weekly time step during the two seasons is estimated to catch a defined proportion of the biomass at that time, which in the model also has a defined average weight per prawn. This average prawn weight was graded within the model according to the weight categories of Table 1, and assigned a uniform grade and value for that week. The average price per grade of prawns, obtained from Newfish in 2009, was used to estimate the value of the catch during that week. It should be noted, that this is another simplifying assumption, as in reality the catch during any week would contain a range of weekly cohorts and so a range of size classes and grades of different values.

Cohort Starting Size:

This static population model is given a starting number for the size of the initial cohort of zero age in week zero. This number can be set at any level and any starting number provides the same static view of the relationships between initial size, time, growth, weight and survival. The starting size of the cohort size has been arbitrarily scaled along with the catchability parameter (q) so that at age the cohort is estimated to produce catch rates and catches within the range expected from this fishery. For this analysis a starting estimate for q was provided by Loneragan et al. (2002), and cohort starting size has been scaled around that value to produce sensible estimates.

Economic Model

Price of Prawns

Table 1 contains the price of banana prawns (2003–2008) by grade as provided by Newfish. These data have been used to estimate an average price for the three grades of prawns (right hand column) which were assumed to apply to JBG red-leg banana prawn through this analysis.

	2003	2004	2005	2006	2007	2008	2008	Averages
U/15 (30g)	15.01	13.01	13.27	12.69	11.92	12.56	12.02	**12.92**
U/20 (22g)	13.18	10.73	9.87	9.35	9.35	10.50	9.50	**10.35**
U/25 (18g)	11.00	9.40	9.36	7.59	8.40	9.20	8.50	**9.06**

Table 1. Price data supplied by Newfish and used to estimate the average price for each grade of prawns in AUD$ (right hand column).

Cost of Catching Model

The elements of the cost of catching equation developed for the JBG were also provided by Newfish in early 2009 and are as follows:

- Fuel 2,400l per day @ .68c/l = $1,682
- Consumables fleet = $210 per day
- Consumables Engine = $200 per day
- Packaging = .45c/kg of the catch
- Inward Cost Charges (deducted from the sales price of the catch, regardless of where the boat unloads, to cover company costs e.g. unloading, transportation, stores) = $1.05/kg.
- Crew = 22% of the balance of the value of the Catch, no other costs are deducted from the crew's share.

Thus the cost of catching model is as follows:

1. Daily Gross Income = Daily Catch (kg) x Price/kg

2. Daily Cost of Fishing = Fuel Cost + Fleet Costs + Engine Costs + (Daily Catch (kg) x (Cost of Packaging/kg + Inward Cost/kg))

Thus:

3. Nett Daily Return = (Daily Gross Income – Daily Cost of Fishing) x (1- Crew's Proportion of Profit)

Results

Synthesis of Industry Knowledge

The JBG fishermen told us that, 'if you fish in the JBG you're fishing for red-legs', and that they 'don't really think much about other prawns'. They could not tell us about any opportunities to temporally target clean any of the other prawn species. Although if catch rates of other species are high enough caught when they are scratching around for red-legs catch, they are more likely to keep fishing the area.

The fishermen interviewed described annual patterns of recruitment, growth and movement across the JBG fishing grounds that they believed varied with environmental drivers; principally rainfall driving recruitment rates, and cold water associated with strong south-easterlies affecting growth and catchability.

In the shallows, inshore of the commercial fishing grounds, closer to the nursery grounds along the southern and south-eastern coasts of the JBG, red-leg prawns of all size classes, small to big, can be 'scratched-up' at almost any time of year, mixed in with other prawn species. Although available across broad areas the low catch rates generally makes fishing this area unprofitable. The shallower southern and southeastern edges of the fishing grounds provide similar areas where mixed sizes of prawns, can be found buried throughout most of the year. On average the prawns are bigger and catch rates higher through these fished areas, although there are less of the biggest size classes than on shallower grounds. Either the prawns do not grow in these areas, or, as the fishermen believe, the larger prawns are continually moving out from this area to the adjacent, deeper adult feeding and breeding grounds in 50–90 m.

The fishermen referred to the shallower areas of the fishery, and to the area inshore of the commercial fishing grounds, containing semi-permanent buried dispersions of mixed size classes and species, as the 'base' or 'beginning' of the stock and fishery. Apparently, in some years this is the only part of the fishery that holds prawns. The fishermen associate that with low biomass levels resulting from low recruitment and poor growth.

The main fishing grounds are a minimum of 35 km off shore and depths in 50–90 m. Smaller mature males, aggregate alongside concentrations of the larger mature female prawns. The fishermen try and fish the larger more valuable female areas monitoring sex ratios in the catch closely to optimize catch rates. For some period of the season the adult aggregations drift to the NW along the contour lines. Late in the season the movement of the prawns turns south and the adult prawn aggregations move back towards shallower water. It was apparently just this last phase of the aggregation cycle that was fished in the earliest years of the fishery (1979–1981). The interviewees said this was the normal aggregation cycle during the big years of the mid-1990s, but until 2009 it had not been seen for some years.

The fishermen believed water temperature, monitored as surface temperature, determines the timing and movement of the prawns. If the water doesn't get warm enough the prawns don't grow, and presumably stay on the shallower grounds in the permanent dispersion of mixed size classes. The strength of the SE monsoonal winds also strongly affects the fishery keeping temperatures cool, and the seas too rough for safe effective fishing.

We asked the fishermen specifically about the relative strength of the two annual periods of recruitment and were told that two cohorts were visible in the catches most of the time. Particularly if the shallower grounds in the fishery closer to the nursery grounds were fished. Fishing the deeper adult grounds avoids the by-catch of smaller prawns, and because they normally minimize the bycatch of small prawns, they had trouble gauging the relative strengths of the two cohorts.

Fishing only occurs through the neaps of each tidal cycle, as at the peak of the tidal cycle there are 5-7 m, twice daily, depth changes and the associate current make effective fishing impossible. The fishery is concentrated each year in 'traditional areas' with soft shelly sediments. The fishermen use sounders to search for areas of bottom within the traditional areas, which show signs of 'life' against the bottom on the echo-sounder.

The fishermen explained that there are basically two ways of fishing for red-leg prawns in the JBG:

Red-legs are found both dispersed and buried with other prawn species across broad areas, in which case their presence is not distinguishable from other signs of 'life' on echo-sounders. If there are no better prospects for targeted fishing, fishermen may trawl the areas of dispersed size classes and species 24 h/day trying to 'scratch up a catch'. In some years this is the only type of fishing that takes place.

Red-legs also form mobile schools like the white banana prawn (*P. merguinsis*). At times red-legs aggregate and come out of the sediments to form ball like schools – mainly in daytime and then dispersing again at night time. The fishermen target the balls or schools of prawns on the bottom, using their bottom trawls with head-ropes set 3-4 m above the bottom. At times the schools lift off the bottom 50–90 m, and may swim away 20–40 m above the bottom. The fishermen try and track the schools with their echo-sounders to target the school again when it settles back on the bottom. The fishermen described chasing schools of prawns as a lot of searching and chasing, sometimes several days, for a few very profitable shots (>1,000 kg). Once they find a school they try and keep fishing it as long as it remains visibly aggregated. Sometimes other boats will see a vessel is tracking a school and will join in the hunt. Generally the boats don't see that much of each other, as there have been only 6-10 boats operating full-time in the fishery in recent years.

The fishermen switch between targeted fishing and scratching around, as the opportunity to target dictates. There are less big prawns and fewer aggregations when temperatures are cooler. The fishermen attribute the lack of schooling for the last few years to what they believe has been a low biomass levels. The fishers maintain that 'scratching around' during the early season on the shallower grounds, reduces the opportunity for more profitable targeted fishing in the later season.

The fishermen interviewed all painted a picture of the fishery being pretty lightly fished over the last few years. Without being explicit they also implied that prior to the instigation of the single season, fishing pressure had built up to relatively intense levels, and that the residual level of spawning stock had been declining year on year. It was noted that 2009 was the first year since that period in which there had been targetable schools of prawns throughout the second season. This was taken to be a sign of a biomass, benefiting from a period of low effort, and renewed (2009) flooding in the various catchments, and now rebuilding.

Historic Trends in JBG Catch and Effort Data

The time series of catch and effort data we assembled for the JBG 1979–2008 (Fig. 1) shows that catch and effort has varied over time; effort up to 2,834 boat days per year in 1986, catch to 1,011 t in 1997 and catch rates from 79 kg/boat day in 1980 to 1,006 kg/boat day in 2008. This time series only extends to 2008, catch and effort apparently fell from 1997-2008. The catch in 2009 rebounded somewhat to 533 t.

After this analysis was presented to the NPF Pty Ltd February 2010 meeting, it was discovered that the post-2003 effort data were not comparable with the earlier data, with the second data extraction provided by CSIRO including significantly less zero-catch days than the earlier 1980–2003 extraction. It was beyond the scope of this limited TRF project to resolve this data issue and repeat these analyses. Caution is evidently required in comparing the latter points of the plotted effort and catch rate trends, and on the basis of not being comparable data from the period 2004–2008 were excluded from the models reported below.

Noting this caution, the broad correlation of catch and effort trends over time is of interest. It appears that pulses of good recruitment due to environmental conditions have been reflected in peak catches in 1983, 1986, 1993, 1995, 1997, 2001, 2003 and that these pulses of recruitment have always attracted increased effort into the fishery so that each peak in catch is accompanied by an equivalent and usually greater peak in effort. There is also a clear suggestion that successive pulses of recruitment to the fishery have been gradually declining since the 1980s. This has a hint of gradual overfishing of the spawning biomass so that successive recruitment pulses are smaller and smaller.

This interpretation had near universal support amongst the fishermen interviewed. In their view the slow decline from the late 1980s through to 2004 was indicative of a gradual fishing down of residual spawning biomass levels. There was a generally held view that the low effort levels of recent years had been fostering a recovery in the biomas, despite what had been a series of relatively low rainfall years. In this context, the view was expressed on several occasions that while 2009 was a welcome return to something more like normal, it was still smaller than would have been expected from a comparable pulse in the 1990s, because the residual spawning biomass has still not been rebuilt to 1990s levels.

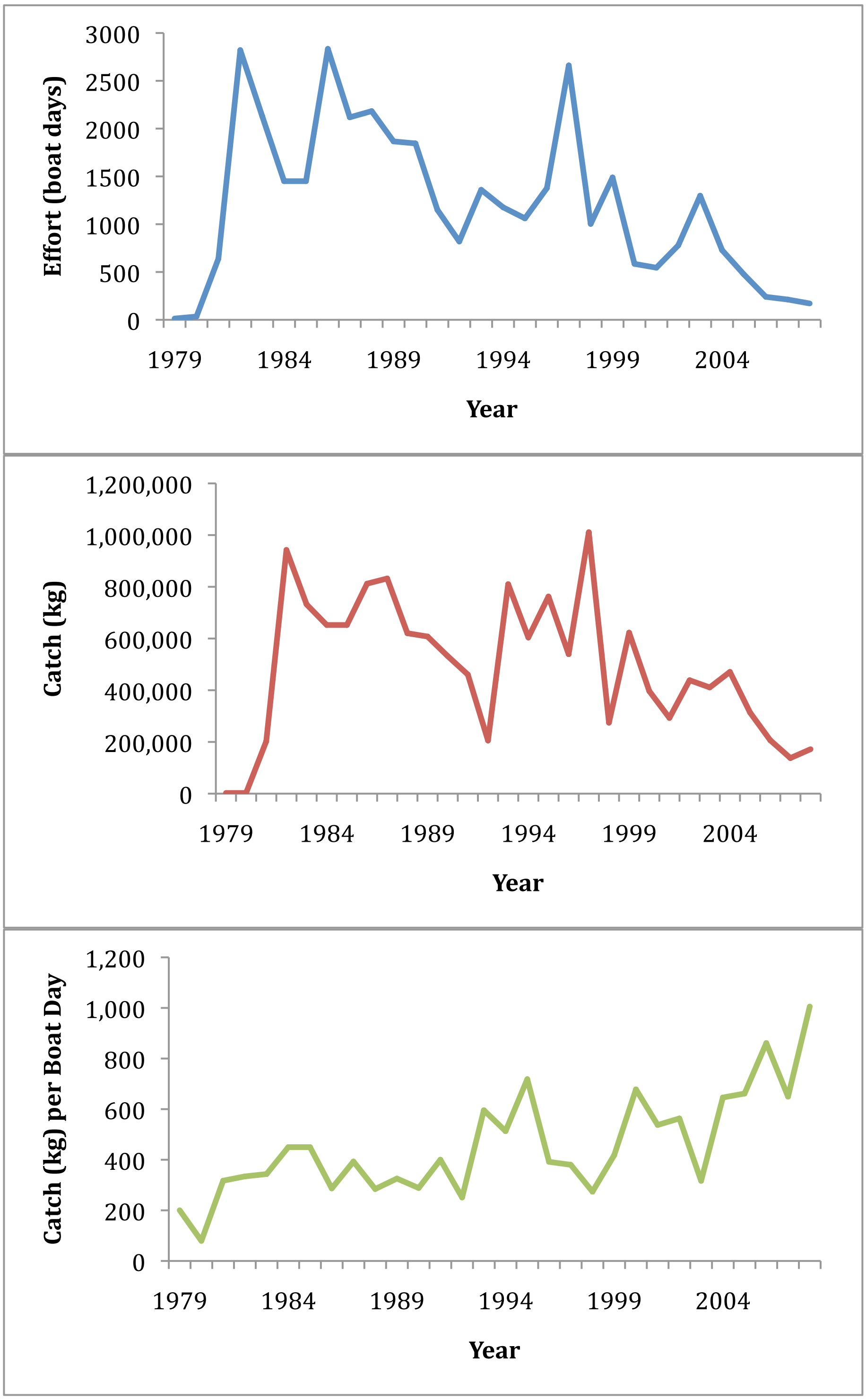

Figure 1. Trends in effort (boat days), catch (kg) and catch rate (kg/boat day) in the Joseph Bonaparte Gulf between 1980 and 2008.

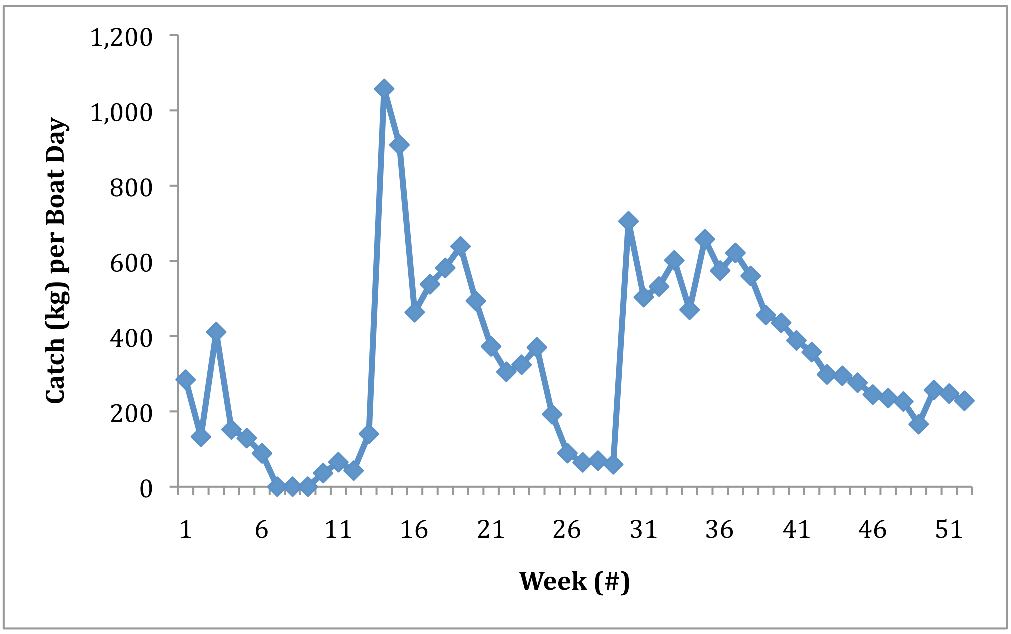

Figure 2. Historic data (1980-2008) showing the average weekly catch rate (kg/Boat Day) plotted against the number of the week in the year (1–52).

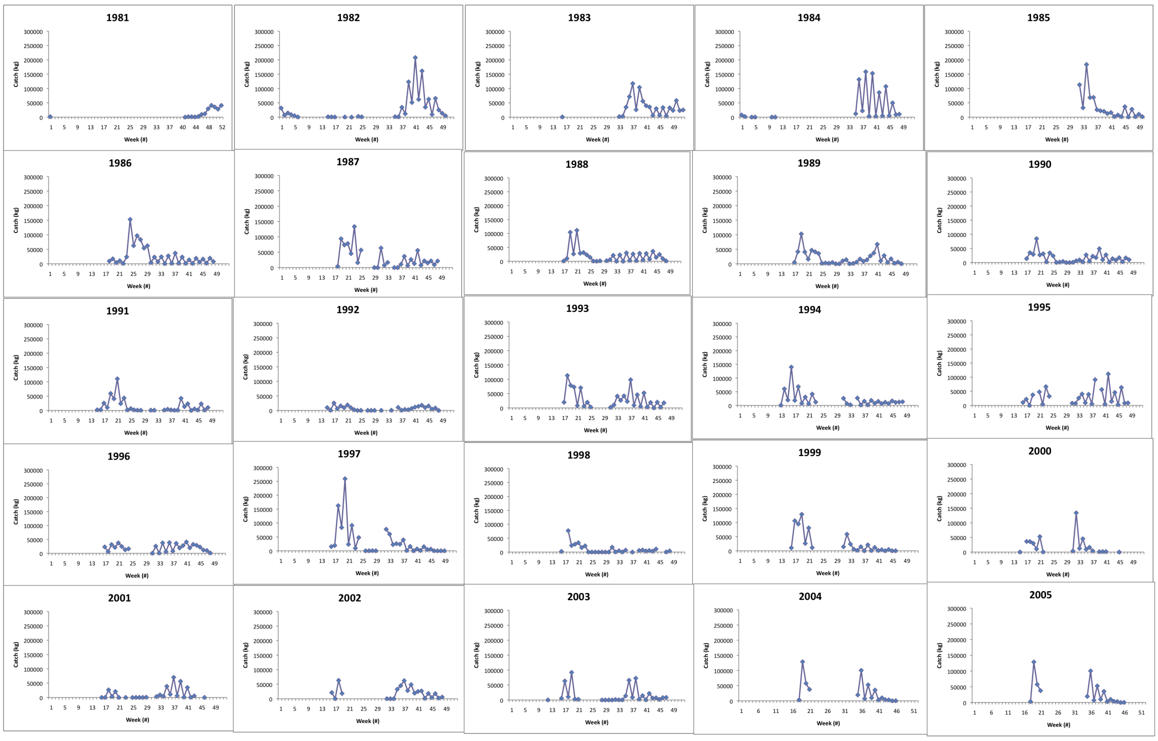

Figure 3 Distribution of catch (kg) by week through the year 1981–2005 showing how the distribution of catch through the year has varied through time.

Figure 2 uses these same data (1980–2008) to plot average catch per boat day as a function of the week of the year across all years. This probably indicates three phases of aggregation through the life cycle of the prawns, which are probably associated with pulses of spawning. The first peak for each new year class occurs in weeks 14–25, the second 31–41, with the hint of the potential for a third and final pulse in week 51–5 of the following year.

Examining the annual weekly profiles of catch and effort throughout each of years 1979–2008 it can be seen that the distribution of catches through the year has varied over time. For convenience of presentation figure 3 only shows the years 1981–2005 but this more limited time series is sufficient to show the main changes that have occurred through the time series. The data clearly indicate that the fishery has had a tendency since its early years to fish earlier and earlier in the annual prawn life cycle. This is a common tendency in most prawn fisheries, and normally inshore closures are instituted in prawn fisheries to curb this tendency to race to fish. The interesting thing about the JBG catch and effort data is that they indicate that in 1981/82 the fishery was fishing the third and final pulse of spawning amongst the last survivors of the previous year class, as fishing started in late December and continued over Christmas into January and February (weeks 1–5). Through the early 1980s fishing began earlier in the season and concentrated mainly on weeks 35-45 the second pulse of each cohorts spawning. By the mid-1980s and early 1990s most of the catching began occurring during weeks 15–25 on the first pulse of each cohort's spawning. All of this is suggestive of the common tendency to race for the fish and is generally associated with a loss of value from the catch and an escalation in cost to the fishery.

Fisheries Model

Figure 4 plots the number of days fished in the JBG against the total catch (kg) recorded in JGB for the years 1979–2003. It suggests that up to 1000–1500 days of fishing catches increase rapidly with increasing effort, but that above 1000 days extra effort becomes rapidly less effective. A simple model was used to describe the relationship between catch and effort based on the equation derived by Beverton and Holt (1957) to describe vessels competing for a limited average biomass.

$$\text{Annual Catch} = \text{Average Biomass} \times (1 - e^{(-A \times \text{Annual Effort})})$$

With this model, the fishery is assumed to be supplied by variable but trendless annual biomass levels, and that each additional unit of effort becomes exponentially less effective, to the power of an exponential curve shaped by the estimated constant 'A'. The assumption being that annual biomass has varied without trend in relationship to rainfall and trendless changes in the annual level of spawning biomass. This simple model estimates an expected catch for each year by fitting combinations of the variable A and average biomass in each year, and compares this to the recorded catch. The best estimates of A (0.00077) and biomass (915) were the estimates that together minimized the simple sum of squares of the difference between the estimated and recorded catches. In other words, when the simple model produced the overall smallest difference between the recorded catch and the catch the model estimated, those estimates were considered best.

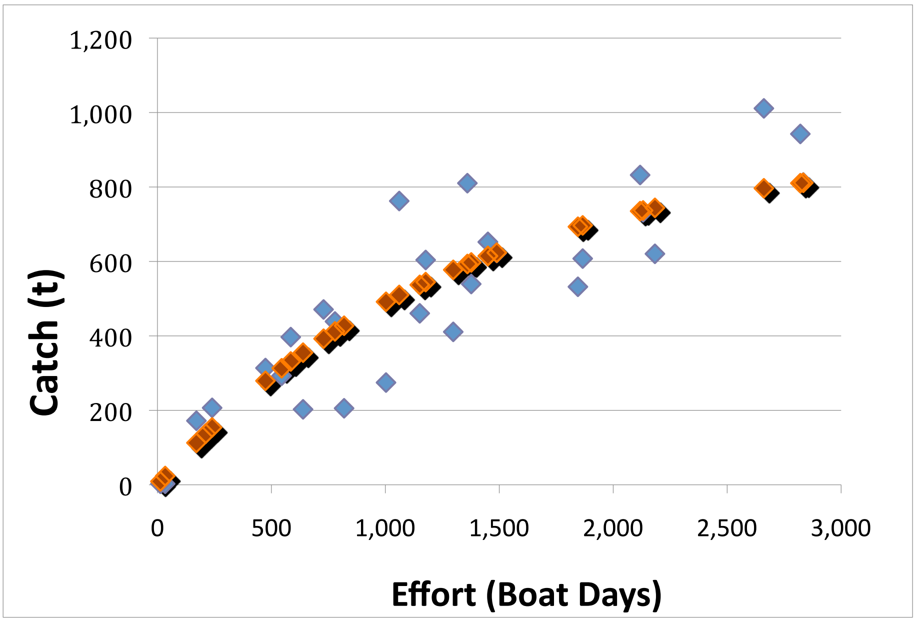

Figure 4. The estimated relationship (red diamonds) between fishing effort (boat days) and catch (t) plotted against the observed relationship (blue diamonds) in the Joseph Bonaparte Gulf between 1979 and 2003.

The red dots in figure 4 shows the relationship between effort and catch predicted by the fitted model. Note this simple model has no capacity to predict annual variation in biomass due to rainfall or depletion by fishing, or annual variation in catch per unit effort due to changes in targeting or fishing season. This is a simplistic model but in this initial analysis of the fishery it appears to describe the fishery reasonably effectively suggesting that above 1,000 days fishing per year additional effort becomes progressively less effective. This gradual decline in the effect of additional fishing effort forms the central core of the first of the analyses that follows.

Figure 5 shows a different view of the same relationship but this time plotting catch rate (kg/day) in each year (1979-2008) as the function of effort (boat days) applied in that year, and compared against the recorded annual data points. The greater variability in annual catch rates (200–1000 kg/day) at lower levels of annual effort (<1500 days), compared to the lack of variability at high catch rates (300–400 kg/day) is quite striking. Some of this variability can be attributed to the early development years of the fishery when poor knowledge of the resource can be expected to have depressed annual catch rates. Thus the two lowest catch rate and effort points are from the first two year years of data and because they are probably unrepresentative of the fishery were excluded from the model fitting process. While the highest catch rate points are for the years 2007 and 2008, which were part of the second data transfer, which had a lower proportion of zero catches, and so may not be comparable with data from 1979-2003.

Again the red points shows the models predictions of catch rate for each year, given the level of effort, expended in each year. This view of the model fitting shows that its description of the data is relatively rudimentary, and could no doubt be improved with by resolving the data extraction issue, and explicitly accounting for the different levels of biomass and mixes of targeting which occur, but which this preliminary model averages across. This could be achieved with existing data in a subsequent phase of analysis and model development. However, this simple preliminary model without any explicit assumption about the underlying course of the observed relationship illustrates the relative magnitude of the effect that competition between vessels for a relatively constant level of annual recruitment has on the dynamics of the JBG fishery, and the potential gains to be had by managing the overall level of fishing effort in the JBG.

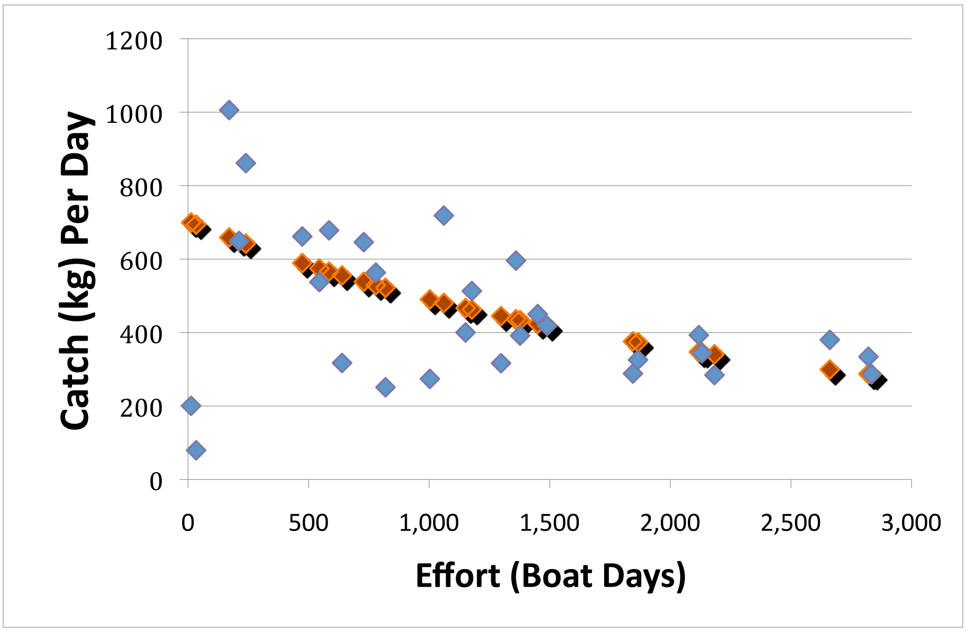

Figure 5. The relationship between effort (boat days) and catch rate (kg/boat day) recorded(blue diamonds) in the Joseph Bonaparte Gulf (1979–2008) and the modeled (red diamonds) relationship (1979–2003).

Taken at face value these historic data as described by the model:

Annual Catch = 915t x (1 - e $^{(-0.00077 \text{ x Annual Effort})}$)

suggests catch per day halves as effort increases from around 500 days per year to around 3,000 days per annum.

In the first of the two bio-economic models presented below, this relationship has been combined with a simple economic model of catching costs to predict th relative profitability of fishing the JBG across a range of effort levels.

First Bio-economic Model of JBG – Fisheries Model

This first bio-economic model combines the fishery and economic models outlined above to estimate the expected catch and costs expected across a range of fishing effort with the aim of identifying optimal fishing levels and maximal levels of profit for the JBG fishery in aggregate.

The relationship estimated above:

Annual Catch = 915t x (1 - e$^{(-0.00077 \text{ x Annual Effort})}$)

was used to estimate the catch and thus catch rate expected on average for each level of fishing effort. These estimates of catch, catch rate and effort were then applied to the cost of catching model to estimate the aggregate level of annual profit expected from each level of fishing effort.

This simple model was used to value the fishery over the potential range of effort levels that have historically been applied to the fishery. The results of this analysis are summarized in Table 2. Successive levels of the economic model are shown, first the value of the catch are calculated as if it comprised of each of the three grades of prawns. Then in the two lower blocks of figures, the value of the catch nett non-crew expenses, and finally in the lowest block the aggregate profit nett all expenses including the crew share. It should be noted that the second model presented below suggests that in this table comparisons should be made diagonally from bottom right to top left rather than reading straight across each row. That is because the higher levels of fishing pressure to the right of the table are likely to produce a catch of smaller less valuable prawns, while the lower fishing effort regimes to the left of the table are generally expected to produce larger more valuable grades.

# Boat Days	**750**	**1000**	**1250**	**1500**	**1750**	**2000**	**2250**	**2500**
Average Catch (t)	**401**	**491**	**565**	**626**	**676**	**718**	**753**	**781**
Value of the JBG Catch ($1000s)								
Prawn Value $12.92/kg	**$5,177**	$6,338	$7,297	$8,087	$8,740	$9,278	$9,723	$10,090
Prawn Value $10.94/kg	$4,384	$5,367	$6,178	$6,848	**$7,401**	$7,857	$8,233	$8,543
Prawn Value $9.93/kg	$3,979	$4,872	$5,608	$6,216	$6,717	$7,131	$7,473	**$7,755**
Profit After Expenses ($1000s)								
Prawn Value $12.92/kg	**$3,045**	$3,561	$3,897	$4,085	$4,152	$4,117	$4,000	$3,813
Prawn Value $10.94/kg	$2,251	$2,589	$2,779	$2,846	**$2,812**	$2,695	$2,510	$2,267
Prawn Value $9.93/kg	$1,847	$2,094	$2,208	$2,214	$2,129	$1,970	$1,749	**$1,478**
Profit after Crew ($1000s)								
Prawn Value $12.92/kg	**$2,375**	$2,777	$3,040	$3,187	$3,238	$3,211	$3,120	$2,974
Prawn Value $10.94/kg	$1,756	$2,020	$2,167	$2,220	**$2,194**	$2,102	$1,957	$1,768
Prawn Value $9.93/kg	$1,440	$1,633	$1,723	$1,727	$1,661	$1,537	$1,365	**$1,153**
Profit as % of Costs								
Prawn Value $12.92/kg	**85%**	78%	71%	65%	59%	53%	47%	42%
Prawn Value $10.94/kg	67%	60%	54%	48%	**42%**	37%	31%	26%
Prawn Value $9.93/kg	57%	50%	44%	38%	33%	27%	22%	**17%**

Table 2. Tabulation of model predicted total value, Profit after Expenses, and final Profit after crew share has been paid, estimated over the range of effort levels observed historically in the fishery, assuming a range of values for the catch, corresponding to the average grade prices.

The interesting analysis to be made from Table 2 is how flat the profit trajectory is with increasing levels of effort. This is shown by figure 6 in which are plotted the figures from the bottom section of Table 2. Assuming a price of $12.92/kg is achieved, the aggregate profit from the fishery is estimated to be about $3.2 million from 1500 days fishing, equivalent to a profit of $2,120/boat day. An additional 1000 days reduces the estimated aggregate profit by $0.2 million so that the profit per boat day falls to $1,530. If it were assumed that the higher level of effort also resulted in a catch of prawns worth only $9.93/kg the estimated daily profit would fall to just $460/boat day.

Another way of looking at this dynamic is presented in Figure 7 in which the estimated profits are presented as a percentage return on the cost of production, rather than an absolute profit level. This figure suggests that at low effort levels (750 boat days) the return on costs can approach 85% if the higher prices are achieved, while at high effort levels (2500 boat days) the return on expenditure will fall towards 17% if the prawns are smaller and of lower value.

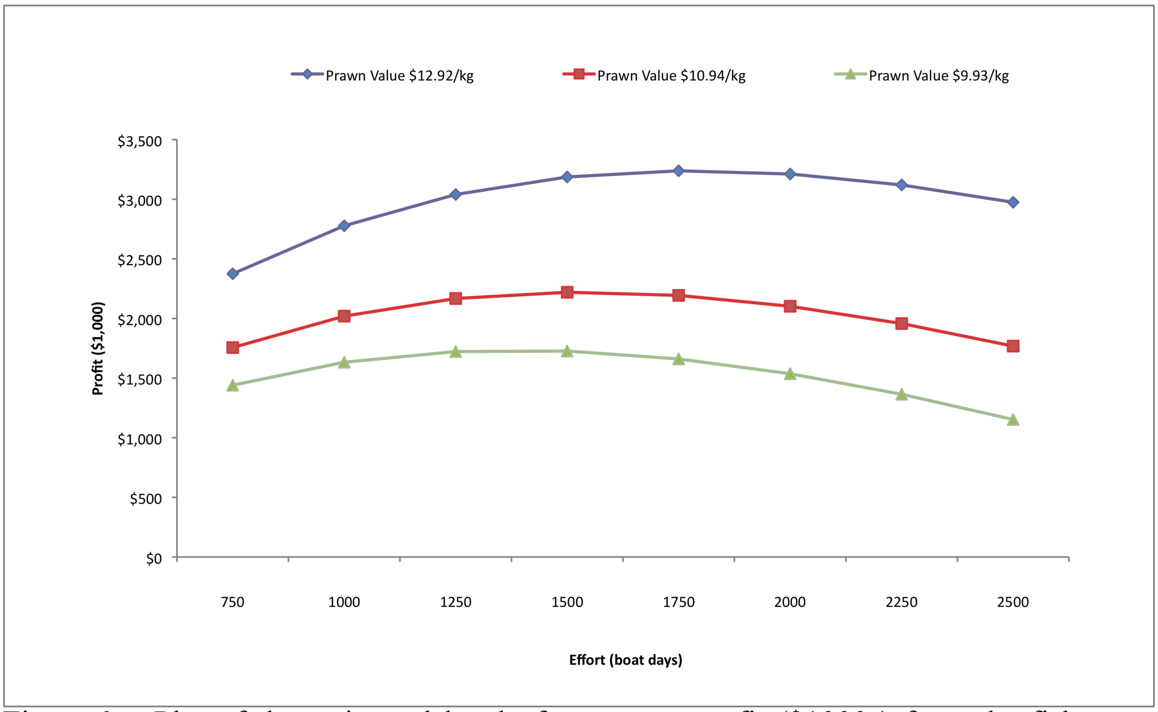

Figure 6 Plot of the estimated level of aggregate profit ($1000s) from the fishery against the number of boat days used to harvest the catch.

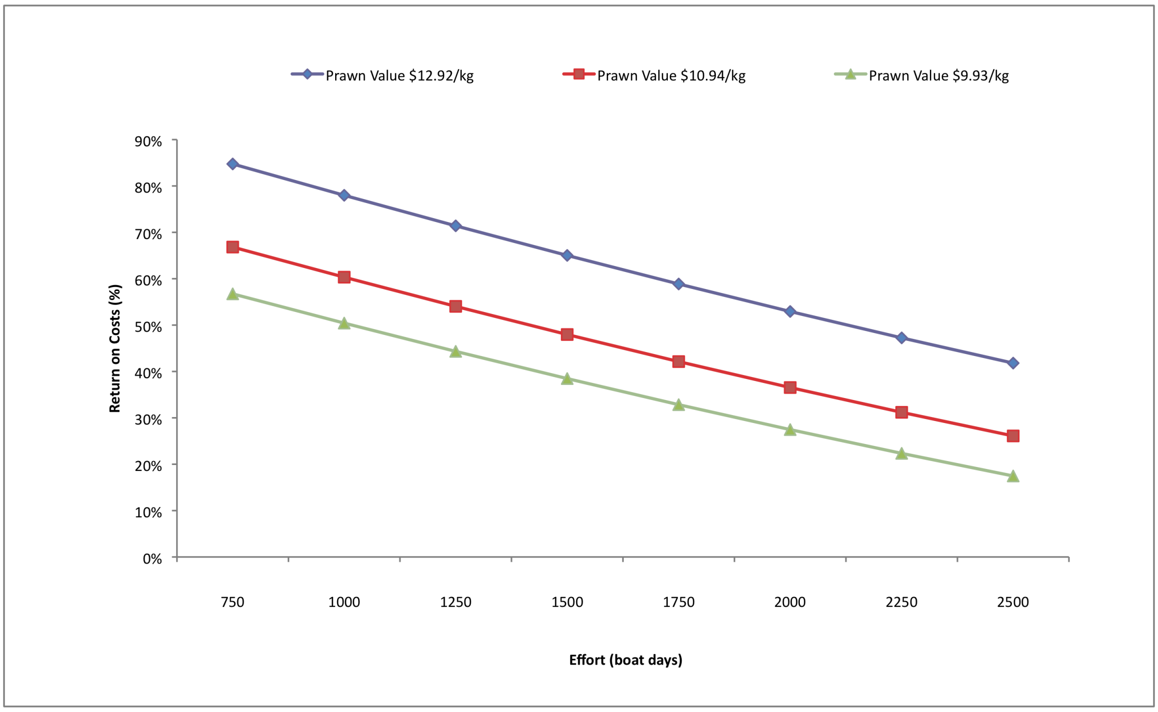

Figure 7 Plot of the estimated return on expenditure (%) from the fishery against the number of boat days used to harvest the catch.

Second Bio-economic Model of JBG - Value-Per-Recruit (VPR) Model

The second model developed by this project is a Value-Per-Recruit modeling (VPR) which instead of using the fisheries data, uses research data on the basic biological parameters of JBG red-legs. The VPR model combines estimates of growth and mortality, with estimates of prawn value by size category to track the value of a cohort as it grows through the fishery in a typical year. The basis of this modeling approach is to assume a single age (week) class of prawns with an arbitrary abundance scaled to support catches of similar magnitude to that observed in the fishery, and then compute their survival, length and weight each week of their life cycle as they grow and are fished by the fishery. It should be noted that this analysis is not analyzing data from the fishery, but rather predicting relative trends and relationships using data provided by biological studies. The absolute values contained in the model's output should not be over-interpreted. The strength of this type of analysis is in using the best science to describe the nature and magnitude of the relative relationships at play in the fishery, rather than accurately predicting the absolute level of profit from the fishery.

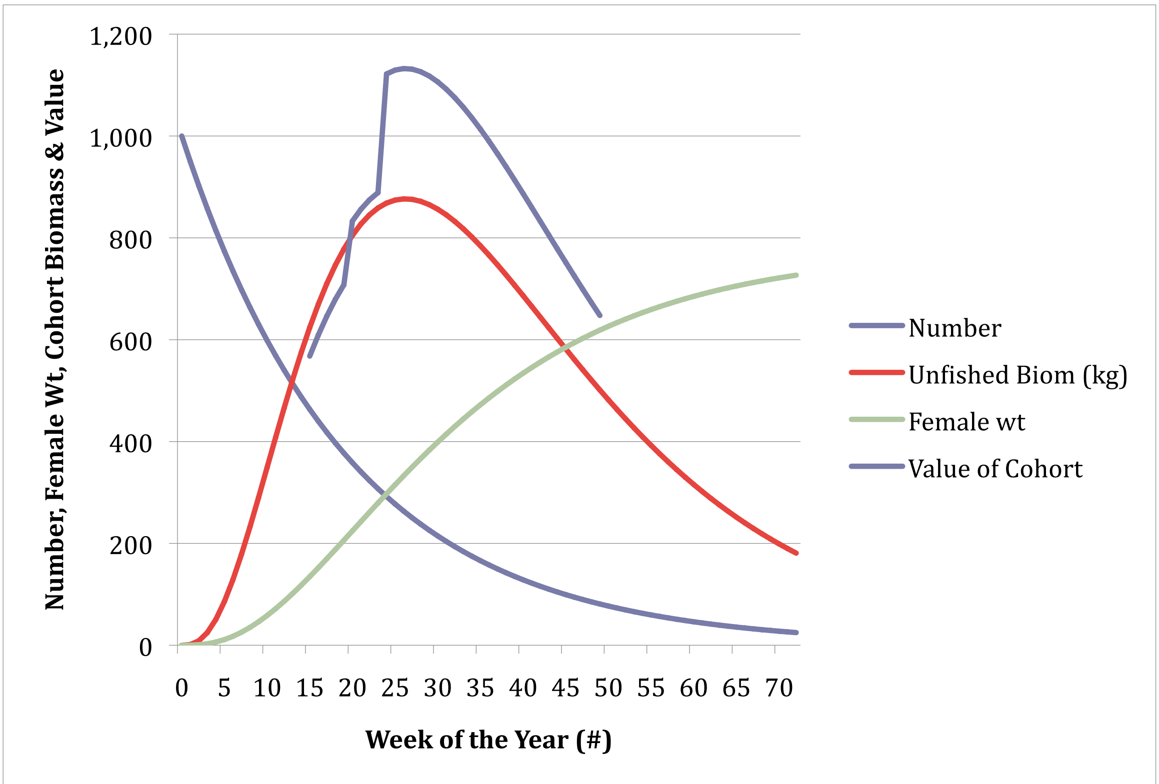

Figure 8 Plots of the basic inputs (starting number, growth and survival) of the JBG Yield-Per-Recruit model and basic outputs; biomass and value of the cohort.

Figure 8 illustrates the basic dynamic of the VPR bio-economic model. From these plots it can be seen that through the assumed 52 week life cycle, the numerical abundance of the prawns declines exponentially while the weight of surviving prawns increases exponentially initially before tapering off. The un-fished Biomass plotted in this figure is simply a product of these two functions so that in aggregate the biomass of the cohort is greatest between weeks 20-35. According to the average prices computed (Table 1) the value of the cohort also peaks at the time of peak biomass. A model of the fishery has been added to this population model.

In this initial version of the model, there is an implicit assumption that the proportion of the biomass spawning in each season is the same. This assumption is modified below in the light of data from Loneragan et al. (2002), suggesting higher levels of effective spawning in the later season than earlier in the year. For convenience, this model truncates the life cycle of the prawns at 50 weeks. Due to the relatively low rate of natural mortality used, the model, if permitted, would predict that some level of biomass would still exist for a third and final pulse of spawning during weeks 53–59 of a cohort's life span. This would correspond to the pulse in catch rates observed during the early years of the fishery during weeks 1-7 of the year (Figure 2). Extending this model to account for survival out to 60 weeks would have some impact on this analysis, increasing the magnitude of the effect being described by the model.

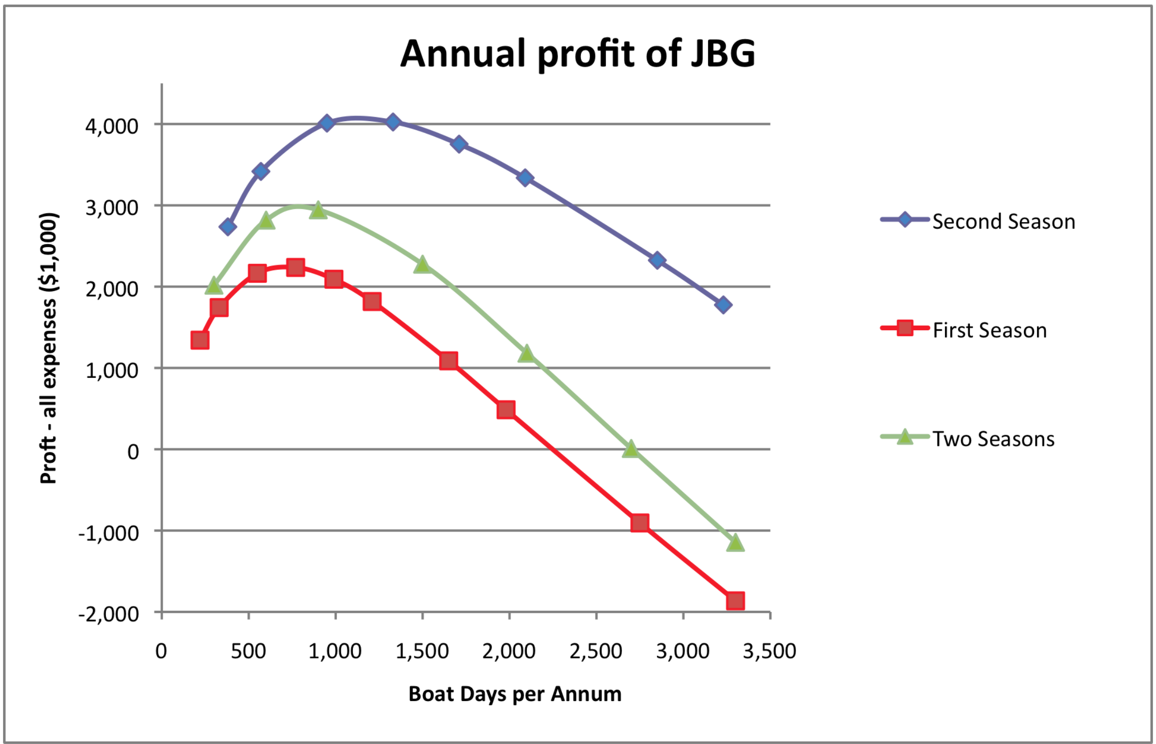

Figure 9. Comparative plots of aggregate profit from the JBG fishery as a function of the intensity of fishing estimated with the Value-Per-Recruit model. Three scenarios for fishing seasons are plotted. The lowest trajectory (red squares) assumes that the days fished are distributed within the first season (weeks 14–24), the middle trajectory assumes effort is distributed evenly through the first and second season (weeks 31–50). The highest trajectory assumes the effort is distributed through the second season.

A wide range of scenarios for fishing effort were explored, the plots presented in figures 9-11 summarize the main results. Figure 9 plots the estimated aggregate profit after all costs against the number of boat days applied to the fishery. Three different scenarios are explored; spreading the effort across the weeks of an early or late season, or across the weeks of both seasons. The assumption is that within each scenario the total number of boat days is allocated evenly across the weeks available under each scenario. Under the range of effort levels analysed fishing the single late season is expected to produce the best aggregate profit from the fishery. Figure 10 plots the same results but as the rate of return on the costs of fishing. These figures suggest that scenarios involving fishing during the first season can produce a loss at high levels of fishing effort.

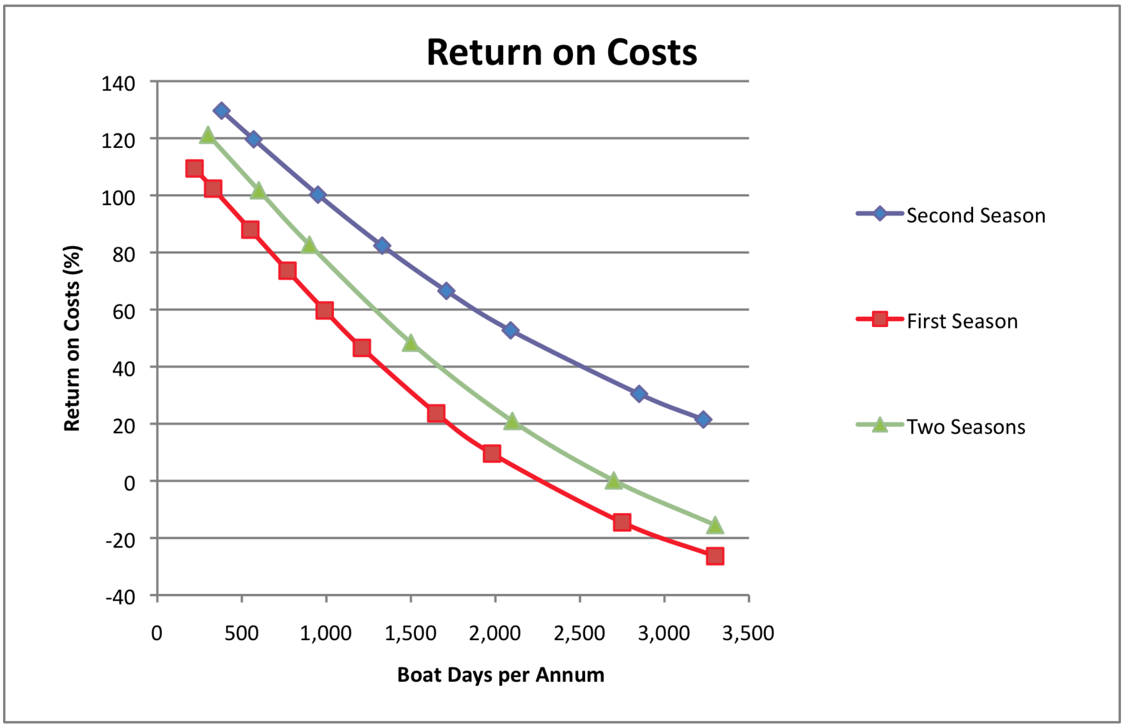

Figure 10. Comparative plots of the percentage return on fishing costs from the JBG fishery as a function of the intensity of fishing, as estimated with the Value-Per-Recruit model. Three scenarios for fishing seasons are plotted. The lowest trajectory (red squares) assumes that the days fished are distributed within the first season (weeks 14–24), the middle trajectory assumes effort is distributed evenly through the first and second season (weeks 31–50). The highest trajectory assumes the effort is distributed through the second season.

These model outputs indicate that fishing the larger prawns later in the life cycle during the second season should produce more profitable outcomes in aggregate. The model estimates gains in gross profit from the fishery of 50 to 100% if the fishing is constrained to the second season, rather than being allowed to spread across the earlier season as well. The relative difference between the management scenarios becomes most marked at higher levels of fishing effort where a fishery allowed to fish heavily on the first season becomes unprofitable. In contrast, the fishery based on older prawns produced relatively stable high returns over a wide range of effort levels (Fig. 10).

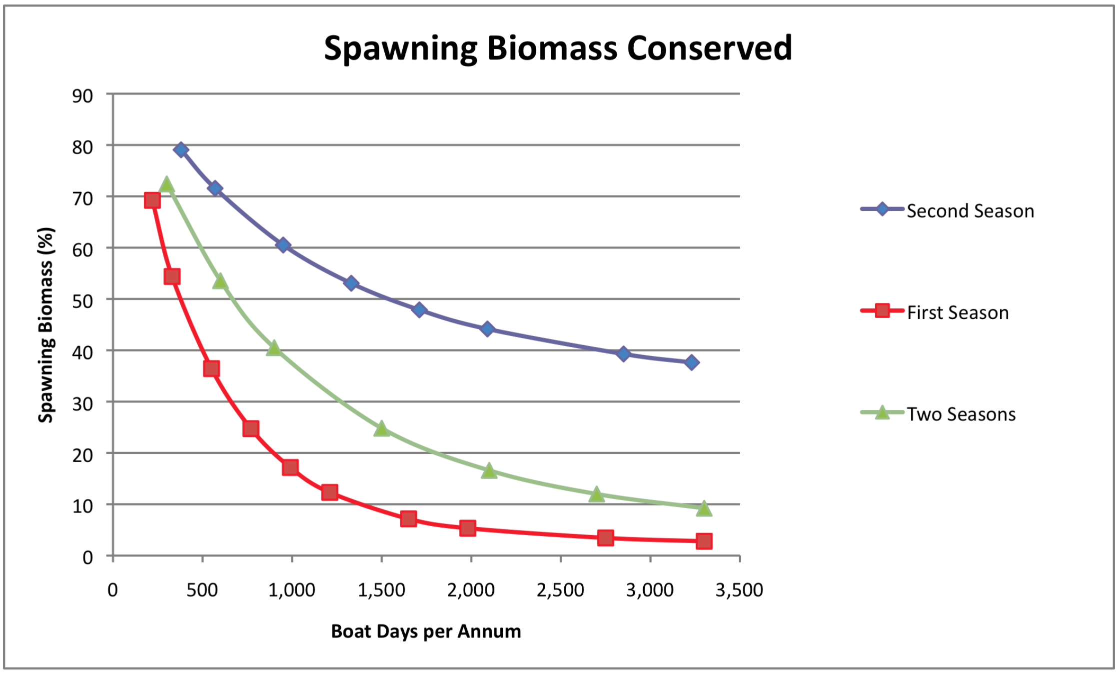

Figure 11. Plots of the same scenario trajectories shown in Figures 9 & 10, this view presents the modeled relationship between fishing intensity and residual spawning biomass, while figure 9 & 10 present the equivalent relationships for aggregate profit and percentage return on costs. The spawning biomass left by the fishery is estimated relative to the spawning biomass expected without fishing.

Figure 11 uses output from the same modelled trajectories as Figures 9 & 10, however in this view the effect of the closure and fishing intensity on spawning biomass is estimated. These plots show that the model predicts clear benefits in terms of conserving breeding biomass by focusing fishing later in the life cycle of the prawns. At high effort levels, the second season scenario conserves 200–300% more spawning biomass than the other strategies, and the difference is still considerable at more moderate effort levels.

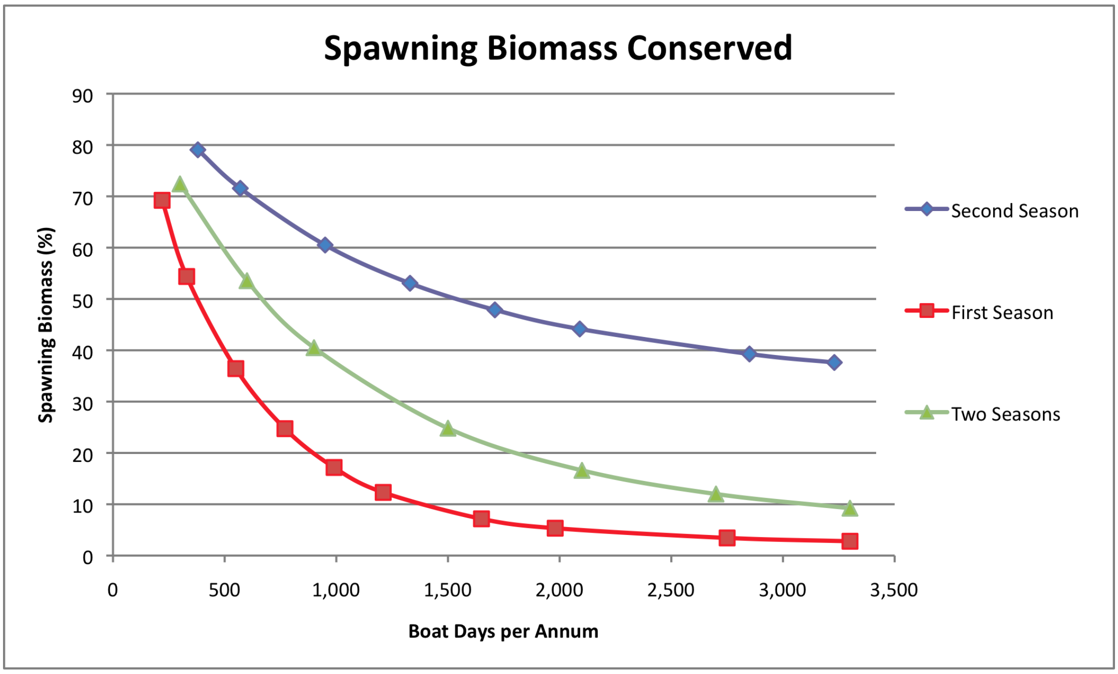

Figure 12. Plots of the spawning biomass conserved and fishing effort for the three scenario trajectories shown in Figures 9 & 10. In this view, the modeled relationship between fishing intensity and spawning biomass is presented using the assumption based on CSIRO observations that 33% of the biomass is spawning in the first season and 66% is spawning in the second season (reference). The spawning biomass left by the fishery is estimated relative to the spawning biomass expected without fishing.

Figure 12 repeats the results shown in Figure 11. However, in this case, the assumption is used that only 33% of the female biomass during the first season is spawning while 66% of the surviving female biomass spawns during the second season. These were the ratios observed in CSIRO studies (ref) and if incorporated into the analysis of spawning biomass, it suggests that at the moderate to high effort levels seen in this fishery at times, particularly during from 1983 to 1990, early and late openings may have reduced spawning biomass to <10% of the recruited biomass level and coinciding with a series of low rainfall years could have caused biomass declines inferred by the fishermen.

Influence of rainfall on catch

Loneragan et al. (2002) explored the relationship between the catch of red-leg banana prawns and rainfall in the Joseph Bonaparte Gulf for the years 1983–1999. Stepwise multiple regression analyses were carried out to examine the relationship between annual catch and the total annual rainfall from July of one year to June of the following year and the monthly rainfall from November until April. A second multiple regression was used that included the annual effort and finally the annual CPUE was regressed against the rainfall variables. The distributions of the variables were checked for normality and where appropriate, the data were transformed before analysis. The rainfall data for this analysis came from the monthly average of 22 Bureau of Meteorology recording stations in the region.

Those analyses showed that January rainfall was the only variable fitted to the multiple regression for annual catch with rainfall variables and explained about 20% of the variation in the relationship (Loneragan et al. 2002). When effort was added to the independent variables, it accounted for 50% of the variation in catch. Annual rain and November rain were also fitted to this multiple regression and the three variables in the multiple regression together accounted for about 72% of the variation in catch. Annual rainfall and November rain were both fitted to the multiple regression equation for CPUE and together accounted for about 55% of the variation in CPUE (Loneragan et al. 2002).

The analysis of Loneragan et al. (2002) was updated and the pattern of residuals explored in the relationship between rainfall, and catch and effort as described by the Fisheries Model developed above. The log of the annual rainfall from July to June explained about 30% of the variation in residuals – as rainfall increased, above trend catches (positive deviations) were more common than at lower rainfall. Above an annual rainfall of 900 mm, five of the residuals were positive and two were marginally negative, while below 900 mm, 66% of the residuals were negative (10 points) and only 33% positive (5 points). Rainfall therefore appears to influence the recruitment of red-legged banana prawns to the Joseph Bonaparte Gulf.

However, this relationship with rainfall appears to be weaker than for banana prawns in some regions of the Gulf of Carpentaria. In the south-eastern Gulf of Carpentaria, rainfall accounts for a greater proportion of variation in the annual catches of the banana prawn (*P. merguinsis*), with the log of January rainfall accounting for 54% of the variation in catch and the log of February rainfall accounting for a further 14% of the variation (Vance et al. 2002).

Increased rainfall has been shown to have a strong influence on populations of juvenile banana prawns in estuaries at Karumba and Weipa in two field studies spanning four years (1975–1979) and six years (1986–1992) respectively (Staples and Vance 1986, Vance et al. 1998). In both these studies, juvenile banana prawns were seen to migrate out of the estuaries following heavy rainfall, behaviour that may be related to juvenile banana prawns being more tolerant than adults to low salinities. It has been shown experimentally that larger *P. merguiensis* are less tolerant of low salinity than small *P. merguiensis* (Dall 1981). Thus the correlation between rainfall and banana prawn catches in the south-eastern Gulf of Carpentaria is generally assumed to be the effect of rainfall on the catchability of the prawns; causing the prawns to move from one location (the estuary) to another (offshore waters) where they can be targeted by the fishing fleet. However, it is also possible that rainfall may increase commercial prawn catches by affecting the biological productivity of the prawn population, with increased rainfall leading to bigger populations by improving growth and survival rates.

Discussion

The results from both bio-economic models suggest that controlling the intensity of fishing (boat days) and catching larger prawns in the second season can significantly improve the aggregate profitability of the JBG fishery. Both the timing of the fishing season and the intensity of fishing should contribute to determining both the size and value of the prawns taken. While fishing intensity determines the cost of fishing. The Value-Per-Recruit model also suggests that confining fishing to the second season conserves a greater level of spawning biomass.

The two alternative modeling approaches used differing sources of data; fisheries data in the Fisheries model, and research estimated biological parameters in the Value-Per-Recruit model, but both describe the same phenomena and suggest a similar order of magnitude in the differences between the alternative scenarios for openings. How should the results from the two studies be regarded in relationship to each other? It would not be sensible to suggest the effects described are independent of each other and so additive to each other. A better interpretation is that the first bio-economic model, the Fishery model, describes the dynamic as experienced in, and recorded by, the JBG fishery. While the second bio-economic model, the Value-Per-Recruit model is a biological analysis showing more profitable quantities of larger prawns are produced later in the life cycle along with higher levels of spawning. So to some extent they are alternate descriptions of the same phenomena, the Fisheries model providing estimates from reality, backed up with theoretical estimates from the Value-Per Recruit model. This agreement between the differing models and data sources suggests that the finding that profits from the JGB should be maximized at moderate effort levels and fishing in the second season, is a robust finding.

Taken together these analyses show the available evidence suggests a strategy of moderate fishing pressure in the second season alone should produce superior outcomes in terms of profitability and conserving egg production. These analyses suggest that on average such a strategy should increase aggregate profits from the fishery 50–100% above the alternative fishing scenarios analysed with parallel gains for the amount of spawning allowed each year.

The principal limitation of the VPR model is the assumption that a single cohort passes through the fishery, when recruitment actually occurs over a broad period of the year. This limitation could be addressed through further data collection and developing better specified models. However, the general result from this preliminary modeling is valid; there is value in catching bigger prawns at higher catch rates.

Besides managing the timing of seasons, our interviews with JBG fishermen also suggested potentially for managing size and catch rates by re-defining the inner boundary of current fishing grounds. If we take the view that recruitment is actually spread broadly through the year so that it is almost continual, the Value-Per-Recruit model with its assumption of uniform age and growth becomes unsafe. The same phenomena of growth and increase in value, is still observed, but spread out in time through the year so that season closure are less effective. In this case, size and catch rates might be as effectively controlled by enlarging the shallower area of nursery grounds inside the current fishery, and limiting the extent of the area and impact on smaller cohorts of shallower fishing.

February 2010 Meeting with NPF Industry Pty Ltd & the Ongoing Debate

These were the results presented to the 18-19 February 2010 meeting of NPF Industry Pty Ltd and they engendered considerable discussion amongst its members.

The meeting seemed to broadly accept the conclusions from the analyses – that fishing the JBG with moderate effort levels and later in the season should optimize the value of the JBG production to industry. During the formal meeting and the one-on-one discussions around the meeting, members expressed gratitude and appreciation for the analyses that had been presented to them. In particular, members appreciated being presented the time series data for the JBG resource, and the simplicity of the modeling, that they could follow conceptually.

There was however a strong minority opinion in opposition to the proposition of continuing to manage JBG with a single late opening. This view seemed to be based on two other inter-related issues that were independent of the modeling presented, or distribution of prawns through the year. It was focused more on:

1. That the value of the JBG for NPF Pty Ltd members should not be considered so much in terms of optimizing the value of JBG production, but in having access to the JBG fishing area earlier in the year so that NPF wide fleets can be kept more optimally occupied through each fishing year, and

2. There is not enough fishing capacity left in the NPF fleet to optimize landings from a single late season. i.e. without opportunity to fish in the first season JBG effort and catches will be smaller than optimal.

The first of these issues highlights the need to define management objectives for the JBG: Is it the optimization of return from the JBG, more or less as a unit? Or should it be fished strategically at lower levels of value to meet the broader objectives of its fleet's fishing plans? There is no black and white answer to this question, as working strictly towards optimizing the return from all the NPF stocks at the same time would be logistically challenging. And, as noted by Dr Kompass in NPFRAG's comment, there is no single best solution to this economic equation anyway. But working with both the timing of seasons, and adjustments to the area of fishing grounds, better mutually more optimal options might be found across and between broad regions of the NPF.

Allowing multiple operators to individually maximize individual objectives in a fishery leads to the 'race to fish' which is widely recognized as leading to over-capitalization and the erosion of the value of a resource (Hardin 1968). Our analysis of the catch and effort time data strongly suggests the JBG has a history of effort levels increasing rapidly during and immediately following pulses of high catch rates, and also that the combination of heavy fishing and low rainfall through the early 2000s reduced residual biomass and annual recruitment to relatively low levels. So we believe that at some level NPF Industry Pty Ltd has a demonstrated need to manage effort flows between component stocks in the NPF, or it could see the broader value of its resource diminished by local depletions.

The challenge for NPF Pty Ltd is finding the balance between, absolute freedom for individual fleet plans, and controlling effort flows between component stocks adequately to ensure reasonable value from each stock.

The second point (above) became the focus of some discussion in the formal presentation to the February 2010 meeting, and again the following morning, when the meeting asked for some follow up discussions. The view being put at that time was that the analyses presented suggested that the current fishing capacity will not allow a single late season to optimize returns because catches will be smaller than optimal. In this view, post fleet-rationalization in the NPF, there is no longer the fishing capacity left to optimize JBG harvests, and those from the GoC as well. The opportunities for fishing will always be superior in the GoC stocks and JBG will not be fished down again. There was much discussion on this point and divided opinions at the meetings attended.

The issue was raised again by the NPFRAG in their comment on the draft report;

> 'The central issues were? that the report looks at effort and boat days which are much greater than those currently in the fishery (around 200 boat days) and the graphs in the report tend not to display information at the current levels of effort. The RAG feels that the report needs to have more recognition of where the fishery currently is (effort levels) compared to the much higher effort levels discussed in the report. The RAG noted that the optimal effort of 800 days is discussed in the study, but the fishery isn't achieving this and is not likely to in the near future. As a result, it is not that the results presented are incorrect, but the report tended to lack some relevance in its discussions about optimal returns based on different fishing seasons because of this.'

At the NPF Industry Pty Ltd meeting in February 2010, discussion turned to the meaning of the latest data points (2009 & 2010), which had been just provided by CSIRO, because the targeting of schools had been a feature during those two years. Responding to the meetings request, these two data points were entered during the meeting amid much discussion, and apparently showed very high catch rates from very low effort. Taken at face value, adding these data points into the analysis would suggest that average annual catch rates, well in excess 1,000 kg/day, are achievable from this fishery and perhaps that an annual catch of 500–600t/annum could be caught with 400–500 boat days.

This view received strong support at the February 2010 meeting from those members supporting the view that fishing should be confined to a single late season. However, as we argued at the meeting, that was not a safe use of the analysis at that point in time. The data in the time series with low levels of annual catch and effort have highly variable catch rates with some very low and some very high catch rate years (see Figure 5). These low effort years come from very specific and unique periods in the history of the fishery;

- from the very early years of the fishery when the fleet was still learning how to target red-leg prawns, and
- from the very recent years in the time series.

Targeting patterns have evolved over time, and varied between time periods, and the current analyses makes no allowance for the effect that evolving targeting patterns, or biomass trends, have had on the observed relationship between effort and catch rates. Much depends on whether the catch can be taken at high catch rates in shots targeted at schools of prawns, or whether dispersed prawns need to be dug out of sediments at lower catch rates. The JBG fishermen we interviewed held the opinion that fishing the early season reduced the level of biomass available to school late in the season to be caught at high catch rates. This suggests another mechanism for enhancing profitability and reducing the level of effort needed to land the JBG harvest that is clearly not reflected in the preliminary models developed by this study, which make no allowance for differing targeting practices.

The data and preliminary models presented do not have the kind of precision that the proponents of the opposing points of view want to support their arguments. These preliminary models cannot be pushed beyond their capacity and then used to build a solid argument. With further development it could have the ability desired, and may well support one of the views being advanced.

In the light of the discussions of the February 2010 meeting and with the aim of informing our gap-analysis, some further analysis of the data were commenced to look for simple targeting patterns in the data and determine the extent to which they have changed over time, or between periods of time, and how that might be accounted for within our analyses. This simple next step into the next phase of analysis of these data immediately discovered inconsistencies in the data structure of the most recent years of the time series of NPF logbook data compiled and analysed in this analysis.

This project began working initially with an extract of NPFlogs up to 2003 provided by Bill Venables in 2005. Later, in November 2009, Eva Plaganyi (CSIRO) provided data covering 2004–2008 and estimates of total catch and effort for 2009 and 2010 were supplied at the February 2010 meeting. These later data (2004–2010) appear to have been extracted differently from the data base to the method applied for the earlier extraction, as the later data contain fewer zero catch days than the earlier time series, so with fewer days of effort they provide systematically higher estimates of average catch rates over time. In fact the 2009 and 2010 estimates provided and plotted at the meeting, apparently contain no zero catch days in the data extraction and so produce the highest estimates of catch rate in the time series.

We assume that these systematic differences in the proportion of zero catch days are due to the data extraction criteria changing, rather than the fishery. Fishing only occurs during neaps in the JBG and targeting vessels may spend several days searching for schools without fishing. We can only assume the selection criteria regarding these zero-catch days changed between data-sets we were given. A relatively simple flaw or gap that can be easily rectified in a longer-term project, but one which could not be addressed in the final stage of this short-term tactical analysis.

The alternative is that the effort data are indicative of changes occurring in the fishery, with targeted fishing becoming invariably successful every day. The gap highlighted here is the need for a complete time series from a standardized data extraction process, and for a more detailed analysis of targeting practices over time and space within this fishery.

The broader impact of the flawed data on this study's results is fortunately relatively limited. An initial version of this analysis was performed using the first set of data 1980–2003 which have an internally consistent level of zero catch days. The relationship between catch and effort derived using this (1980–2003) data series is the one used in this report. When that analysis was initially updated with the addition of the data 2004–2008 the main estimates and results of the analysis were changed relatively little by the addition of the extra 5 data points to the original 23 data point time series. That was the version (1980–2008) presented to the February 2010 meeting. So in terms of the broad-brush analysis presented using the first of our preliminary, bio-economic models, the data problem has not materially changed the basic advice being offered through the life of the project. The fisheries data were not used in the second bio-economic model, the Value-Per-Recruit model, so there was no impact on that analysis.

The discovery of this data issue, does however, serve to underline the argument that these results should not be pushed beyond the original objectives of the project, which were to 'develop a preliminary assessment of the JBG red-leg banana prawn stock focusing on how yields, catch rates and production costs might be optimized in the medium and long term' and 'gap analysis'. In their comments on the draft of this report NPFRAG expressed interest in using this preliminary analysis to determine optimal levels of catch and effort, and in estimating relative opportunity cost of boat days in the JBG rather than the Gulf of Carpentaria (GoC). These broader interests of the RAG identify a gap that needs addressing by with future modeling projects.

Noting the data issues identified, and preliminary nature of these analyses, preclude precise estimates of optimal levels of catch and effort. And also noting Dr Tom Kompas' comment recorded in NPFRAG's comments; that there is no real optimum value to the profit function used. We nevertheless must return to the RAG comment that current effort levels in the JBG are around 200 boat days/annum and unlikely to return to 'optimal' level of 800 boat days indicated by this study.

The first point to be made here is that, the data issue identified above, also impacts NPFRAG's estimate of recent annual effort as being about 200 boat days/annum. The current estimate of effort at 200 boat days/annum contains very few if any zero catch days, while the estimate of 800 boat days/annum derived by this study contains >30% zero catch days which we assumed was related to waiting for neap tides and targeting practices. Assuming a similar level of zero catch days occurred in recent 'low effort' years as incorporated into the 1980–2003 data series and the low effort level recorded in 2005–2008 may still been as much as 50% of the 'optimal' level suggested by our preliminary models.

The second point to make in response NPFRAG's comments, is that the low effort levels in the JBG from 2005–2008 were undoubtedly due not just to the wider fleet rationalization that has occurred across the NPF, but is also a reflection of the low expectation the GoC fleet had of JBG catch rates during those years. In other words it reflected the way the various fleets predicted the opportunity costs of having vessels in the JBG rather than the GoC in those years. This can change. As discussed above the catch, effort and catch rate time series for the fishery (Figure 1) shows strong evidence of cycles of good years in the JBG repeatedly drawing in effort from the rest of GoC, which peaks one two years after the peak of catches.

This has just happened again, the recent increase in catch rates, estimated using the data we have as an increase from 650kg/day in 2007 to >1,000kg/day in the 2008 season, resulted in JBG effort increasing from 171 days in 2008 to 456 days in 2009. These estimates of annual effort have comparable levels of zero catch days, and so should be comparable.

Given that the effort estimate of 456 boat days in 2009, apparently contains very few zero catch days, while our modelled rates of effort contain a considerable proportion, it may be that the JBG fishery had already returned to a level of effort equivalent to the 'optimal 800 boat days' of NPFRAG attributes to this study. This rebound in effort is occurring at a time when the evidence suggests the residual biomass of the JBG stock continues to rebuild. If the JBG stock continues rebuilding, it is likely to attract further increases in effort. Consequently, we refute the NPFRAG's contention, that the effort levels we analysed are not relevant to the modern JBG fishery, because effort levels that high are unlikely to be achieved in 'the near future'. The moderate levels of effort this report suggests would optimize returns from the JBG may already have been surpassed by 2011.

Resolving the underlying data issue discovered here, and conducting more detailed analysis of targeting trends are clearly the gap identified by the need for this discussion.

Regardless of the unresolved nature of the debate, the robust discussion that took place on the floor of the NPF Industry Pty Ltd meeting in February 2010 clearly indicated the direction that the members would have like to have taken the analyses, or would like this analysis to take next. The members were interested and stimulated by being shown, and having the opportunity to discuss and analyse basic trends in their own fisheries data, and were keen to apply simple trends in data to analyse and discuss opportunities for optimizing components of the NPF resources.

The broader interests displayed by the RAG in developing the approach further was also encouraging.

Grading Data

The project proposal intended collecting and applying industry's grading data to the issue of the timing of recruitment through the fishery, which at the time was seen as a major point of contention in the JBG discussion.

Interviews conducted during the project suggested that the companies involved do not tend to retain grading data for more than 1-3 years and during this time period the fishery has only fished the single later season preventing comparison of the grade composition between early and late seasons.

Discussion at the February 2010 meeting identified one company with details of crew payments going back to 2001which contain data on the quantity of the different grades collected. These data are apparently hard copy and in archival storage facilities. With records in hard copy a level of resources and time beyond that available to this project may have been required to make a proper analysis of this new data possible. The aim was to access these data and at least evaluate their utility and the resources that would be required to make use of them. Despite repeated attempts to follow up with that company it proved impossible to arrange access to these archival data, and consequently no assessment of their potential utility was possible.

Benefits

As planned the project prepared and presented an analysis of the JBG red-leg banana prawn fishery to the NPF Industry Pty Ltd meeting that occurred in February 2010 and amongst other things discussed JBG management for 2010.

The stated aim of this project was to inform and facilitate NPF Industry Pty Ltd's:

1. Decision making about opening the JBG in 2010, and
2. Development of a plan for developing their capacity to gather and evaluate data needed to optimize prawn production from the JBG in the medium term, and from other stocks in the longer term.

The members of NPF Industry Pty Ltd benefited by having the available information about JBG synthesized, analyzed and presented for discussion at their February 2010 Brisbane meeting in the form of a written report circulated beforehand, and an audio-visual presentation, and follow-up discussions. The members expressed their gratitude to the project team at the meeting for making their own data available to them in the form of charts of time series and interpreted through simple easily understood models. Discussions also occurred between the project team and NPF Industry Pty Ltd about extending the approach and developing industry capacity to gather and evaluate their basic fisheries data. The project team will present this final report to NPF Industry Pty Ltd and continue these discussions.

From the point of view of the project team, it would seem that a benefit that NPF Pty Ltd may well have wanted from this project, even if it was never stated, was the scientific persuasion of all members to a unanimous point of view about the number and timing of seasonal openings in the JBG. Unfortunately it would seem this debate is more about the value of fishing flexibly amongst the individual NPF resources throughout the year, against the value of optimizing the value of specific NPF resources. In this context this analysis was never going to impact entrenched points of view. However, a benefit that was apparent was that it became clear during the meeting that members were generally supportive of optimizing the value of JBG production with a single later season, and the counter view was held strongly but by a minority view. There was strong formal and informal support for industry engaging with a small cost-effective research process to support a more intelligent use of data to inform management discussions about optimizing the value of the NPF resource.

So in summary, generally the predicted benefits for the project were delivered to the members of NPF Industry Pty Ltd. Although the extent to which the report presented facilitated decision-making about the 2010 JBG can probably be debated, as it appeared that two polarized views persisted throughout the project. Comments provided on the draft report by NPFRAG seem to confirm this and the benefit statements from the executive or membership of NPF Industry Pty Ltd will probably provide a further independent confirmation in this regard.

Further Development

One of the objectives of the original proposal was to undertake a Gap Analysis on the data and information available for the JBG and provide analysis on what data would be most cost-effective for improving the information base for managing the JBG resource and NPF resources more generally.

The immediate results suggest that some millions of dollars (50–100%) might be added to the aggregate value of the JBG resource by managing the intensity, timing and location of fishing. Much of what is required management-wise is clearly already in place. And so by implication in simple terms, most of what needs to be known to manage this stock simplistically towards an optimal value is already known to the level of detail required.

Although in most cases the existing data does not seem to be being applied to this end. It was striking how enthused and interested industry members became looking at and discussing analyses of basic trends in their own data. It was evident that this is not something that normally occurs, but which could be used effectively in facilitating policy development by NPF Industry Pty Ltd.

In the context of developing this approach further and the decision that has been taken to implement ITQ management in the NPF, there are several questions that need answering because they influence the direction that should be taken in terms of data collection, data analysis and science based policy development.

Will the new management direction provide some of the tools needed for industry to manage local stocks, like the JBG, at moderate levels of effort? If it is to be managed as a separate JBG TAC, does industry want the ability to fish the annual variability of the biomass, or will it be content to simply crop off a conservative stable TAC each year? A system that allows some inter-annual variation in the TAC will require seasonal surveys and monitoring, and the development of real-time models of growth and movement out across the nursery and fishing grounds. This could clearly be developed, but will require a large investment in at-sea research and data collection, both to build precision into the existing estimates of the basic population parameters, and then the monitor inter and intra-seasonal variation in recruitment and growth. At the NPF Industry Pty Ltd meeting in February 2010 members expressed a clear and strong opposition to any further large-scale investment in research in the current economic environment. So in this discussion, no further consideration is given to this type of research agenda.

As outlined to NPF Industry Pty Ltd at the February 2010 meeting, an alternative low cost approach to applying data and scientific analysis to optimizing the value of NPF resources would be to extend the current approach into an on-going studentship by which Dr Prince and Prof. Loneragan could supervise assembling data sets, conducting analyses and developing more detailed bio-economic models on the more important NPF resources, in parallel to extending this current JBG analysis. What is proposed here, is a small on-going unit at Murdoch University that could develop a capacity to act as an analytical team to support NPF Industry Pty Ltd policy development.

This approach could start by improving the rigor of the current JBG analysis by addressing data consistency issues, and studying the impact of changing targeting patterns on the CPUE trends being analysed. Applying simple analytical techniques quickly and simply to some other NPF stocks would feed further discussion with industry of the potential gains to be made by optimizing local harvest strategies. Having modeled the dynamics of several component stocks, within a Harvest Strategy Evaluation (HSE) modeling framework, it would be then become possible to examine even the broader NPF-wide issues of interest to NPFRAG, the balancing of opportunity costs by fleets between component areas of the NPF, and the way this drives fishing patterns and overall profitability in the NPF.

Student based projects could be used to work cost-effectively with industry on basic biological studies, collecting samples locally from NPF catches transported to Perth for processing, to refine basic parameter estimates as required. Academics, NPF Industry Pty Ltd, and AFMA working together within an ITQ system may be able to organize cost effective structured sampling programs using some of the ideas developed in the SESSF for using quota for research. This could allow accurate descriptions of the growth and movement of prawns across the main fishing grounds, enabling the development of better models for optimizing of fishing grounds and seasons across the NPF.

This project analysed data extracts from the NPFLOGs database maintained by CSIRO in Queensland The extracts now held by Biospherics Pty Ltd, South Fremantle, WA on archival flash drives are shown by the discussion above, to be flawed by having being extracted in different episodes with variable data extraction protocols, and are of strictly limited value for further analysis. The Modeling frameworks developed for the project are stored on archival hard drive by Biospherics Pty Ltd.

Planned outcomes

Expected Outputs:

1. A review of the historical information available for determining when the fishery should “best be open”; and
2. Develop a long-term approach for industry to collect and assess the information needed to optimise the value of the fishery in the Joseph Bonaparte Gulf.

The output of the project has been a synthesis existing data and research results for red-leg banana prawn (*P. indicus*), in the JBG, and initial simple bio-economic models, along with a preliminary assessment of the JBG fishery and when the fishery should open. Gaps knowledge and data have been surveyed. This outputs, in the form of draft written report, presentations and follow-up discussions on these analyses was provided to a meeting of NPF Industry Pty Ltd in Brisbane, February 2010. The outcome of this was that the industry Company was able to discuss future management of the JBG in the context of the available scientific information. Beyond the dialogue involved in finalising this report the project team has had no further opportunity to discuss the outcomes of this project. However we assume that the presentations made along with the earlier drafts of the report which were widely circulated, have had the tactical impact originally intended for this belated final report.

In comments provided on the final draft of this report AFMA noted; “the NPRAG, NORMAC and AFMA have largely reviewed the work conducted and implemented management responses accordingly”.

Through the analyses and discussions with industry, basic gaps have been identified in the way industry is failing to inform itself with simple analyses of the various NPF resources. By invitation, the project team could develop with industry a long-term strategy for collaboration with independent researchers and analysts, to improve industry’s application of data to policy development.

Conclusion

The project objectives were:

1. Collect and review all existing data and research results for the JBG red-leg banana prawn stock,
2. Develop a preliminary assessment of the JBG red-leg banana prawn stock focusing on how yields, catch rates and production costs might be optimized in the medium and long term.
3. In the context of that preliminary assessment conduct an initial sensitivity analysis of the fishery to identify critical gaps in the knowledge needed to optimize red-leg banana prawn production in the JBG
4. Identify data that would be most valuable for industry to collect, and
5. Present these analyses and findings to an industry meeting to develop a long-term approach to monitoring and optimising the value of red-leg banana prawns from the JBG.

As planned, the output of the project in the form of written report, presentations and follow-up discussions on these analyses was provided to a meeting of NPF Industry Pty Ltd in Brisbane, February 2010 at which the future management of JBG was discussed.

The immediate outcome from this project was a robust science based discussion of the future management of the JBG and suggested directions of how further analysis of the JBG data could support industry’s developing interest in defining the optimal level of fishing effort for the JBG.

The project demonstrated that industry members valued being informed by basic data and simple analyses but this is apparently rare. The project team will develop with industry a cost-effective long-term strategy for collaboration with independent researchers and analysts to improve industry’s application of data to policy development.

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Appendix 1: Intellectual Property

The intellectual property developed through this project is for general publication.

Appendix 2: Staff

Dr Jeremy Prince was the principal researcher funded by this project.
Prof. Neil Loneragan was Co-Investigator.