A Spatial DSS for South Australia's Prawn Fisheries. Using Historic Knowledge Towards Environmental and Economical Sustainability

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Abstract: The Spencer Gulf Penaeid prawn fishery is an example of a sustainable fishery due to close collaboration between fishers, research and government. The fishery has undergone substantial increase in fishing efficiency due to improvement in gear, increase in crew skill, effective use of communication networks for monitoring catch, stock assessment, and for rapid response for change in harvest strategies. Spatial decision-making has reduced the fishing effort to around 60 days per year and less than 10% of the area of the Gulf is trawled, with increasing economic gain due to development of real time adaptive harvest strategies undertaken in collaboration with the fisheries industry. The reduced trawl time and fishery closures, which have been adapted, have important implications for the environment. This presentation describes the process of spatial decision-making and the utility of spatial information techniques using historic spatial data in conjunction with near real-time survey data and statistical risk assessment. The system is implemented linking an Oracle database to ArcGIS, Genstat and Splus and mobile phone technologies.

Keywords: decision support systems; fishery; Oracle; GIS; Statistical models

1. INTRODUCTION

There are three prawn fisheries in South Australia namely Spencer Gulf, Gulf St Vincent and the West Coast all of which are based exclusively on the Western king prawn Melicertus latisulcatus (Penaeidae). (Figure 1).

The Spencer Gulf fishery is the largest Australian producer of Western king prawn (Carrick 2002), and is one of 5 Australian commercial trawl fisheries that produce more than 1,500 tonnes per annum (Tab. 1).

It has long been recognized by the industry that sustainability can only be maintained if the fishing effort is limited in space and time. Such limitations are often difficult define and personal interests may outweigh the interest for the broader good. This is where objective decision support is needed the most.

Currently, the industry is self-regulated, the government bodies play a rather observing role but with strong rights to interfere if necessary. This has not been necessary since the fleet is relatively small with only 39 licenses (vessels) operating and a personal contact between most fishermen. Government authorities have worked in close collaboration with the industry since it has been possible to demonstrate the benefits of reducing the fishing effort.

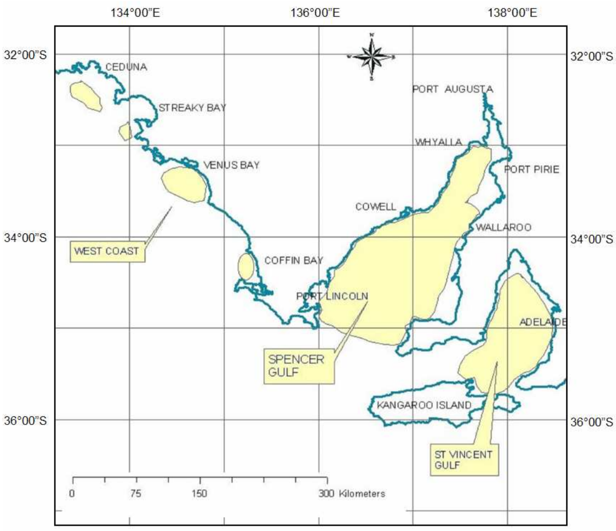

Figure 1: Geographical location of South Australia's prawn fisheries

Yet discussions about how to limit the spatial extent (closures) and the periods of fishing are recurring. In this paper we give an overview of the management and describe the decision support tool that was developed as part of a project funded jointly by the Fisheries Research and Development Cooperation, the Industry, the University of Adelaide and the government authority (PIRSA/SARDI, Primary Industry and Resources South Australia / South Australian Research and Development Institute)

Table 1: Australian prawn fishery Catch statistics for Western king prawns (Melicertus latisulcatus)

Fishery	Vessels	Latitude	Longitude	Catch (tonnes)
Spencer Gulf	39	34° 00' S	137° 30' E	1,600 – 2,500
Gulf St Vincent	10	35° 00' S	138° 10' E	250 – 400
West Coast	3	33° 30' S	135° 45' E	100 – 120
Shark Bay, Western Australia	27	25° 30' S	114° 00' E	1,150 – 990
Exmouth Gulf, Western Australia	13	22° 00' S	114° 20' E	400
Broome, Western Australia	5	18° 00' S	122° 00' E	100
Northern Prawn	150	15° 00' S	136° 00' E	41
Nichol Bay, Western Australia	12	20° 20' S	117° 00' E	43

2. Management Of The Fishery

2.1 Scope of the management plan

The Fisheries Act 1982 provides the statutory framework to ensure the management and ecologically sustainable development of South Australia's marine and freshwater fisheries resources. South Australia has management jurisdiction for western king prawns, from the low water mark out to 200 nautical miles in the waters adjacent to South Australia. The regulations that govern the management of the South Australian prawn fisheries are established in the Scheme of Management (Prawn Fisheries) Regulations 1991 and the Fisheries (General) Regulations 2000. Management plans cover commercial fishing activity for prawns (Melicertus latisulcatus) undertaken within South Australian waters and provide a statement of the policy framework and management strategies.

The prawn management plans do not form part of the Scheme of Management (Prawn Fisheries) Regulations 1991 and do not have any statutory basis. The powers contained in Section 14 of the Fisheries (Management Committees) Regulations 1995 provide the legal basis for the preparation of management plans. Responsibility for the preparation of management plans rests with individual Fishery Management Committees (FMC's).

The Spencer Gulf and West Coast Prawn Fisheries Management Plan operates for a five-year period (from 1998 to 2003), subject to annual review and amendments considered necessary by Minister for Agriculture, Food and Fisheries, the Prawn FMC or the Director of Fisheries.

2.2 Objectives of the management plan

The priority for management of the prawn fisheries is to ensure that the fishery is sustainable so that future generations may benefit from exploitation of the resource. Commensurate with this priority are a number of more specific biological, economic, environmental and social objectives that have been developed by the Prawn FMC to complement the broad directives of section 20 of the Fisheries Act 1982.

McDonald (1998) provides an outline of the Management plan for the Spencer Gulf Prawn Fishery. The primary management objectives for the Spencer Gulf fishery are:

- To maintain the biomass within historical levels and eliminate risk of recruitment decline due to over-fishing;
- To ensure harvesting procedures are directed towards optimising size at capture;
- To maintain and enhance the profitability of the fishery by optimising prawn size, market timing, minimising the costs of fishing and the administrative costs of managing the fishery; and
- To minimise bycatch and trawl impact to the benthos through development of more effective and efficient gear and harvesting strategies.

The management plan provides a statement of the policy, objectives and strategies to be employed for the sustainable management of the Spencer Gulf prawn fishery.

2.3 Reference Points and Performance Indicators

Reference points provide a quantitative measure of a performance indicator that is used as a benchmark of performance against objectives, and can be used to trigger a management response. They are agreed and quantitative measures used to assess performance of the fishery based on defined management objectives. Caddy and McMahon (1995) and others have provided detailed background into the conceptual and applied aspects of reference points for fisheries management. Reference points allow a decision framework to be developed, however, reference points and performance indicators need to be updated and refined regularly. There are two types of reference points for rational exploitation of fisheries namely:

- Target reference points. These are indicators, which are considered the most desirable target from a fishery management perspective.
- Limit reference points. These are threshold levels, which warn that action is needed to rectify the fishery before it suffers longer-term productivity decline.

Morgan (1996) recommended a number of biological reference points for the Spencer Gulf prawn fishery, which have been adopted by the government (PIRSA). The biological reference points consist of the following environmental and economic categories:

Sustainability:

- Maintain exploitation rates at present levels of effort. The target reference point for effective effort is between 70-80 fishing nights while the limit reference point is 80 nights. Effective effort is a function of the amount of trawl effort (hours, days) and the fishing power (or catching efficiency) of the fleet.
- Maintain at least 50 percent of the virgin spawning biomass. This target indicator is the level of the recruit of the year spawning biomass, which remains after fishing and is assessed in November-December. The limit reference point for protecting the resource is that exploitation should not reduce the stock to a level of 40 percent.
- Maintain the recruitment index at a level, which ensures suitable recruitment to the fishery. The reference point is based on assessment of recruits to grounds in the period February to April of each year. The levels set by Morgan (1996) are the numbers of prawns (male and female) <35 mm carapace length (mm CL) in a standardised hour of trawling. Based on Morgan's review (1996) the target reference point will maintain an index of 40 and the limit reference point was set at 35 prawns/hr trawled (see below).

Economics.

- Establish a size at first capture, which ensures the optimum utilisation of the resource. This target considers the size of prawns landed and the price per kg. The management plan states that the size of prawns taken during fishing operations is monitored nightly to ensure that effort is being targeted to prawns which provide the best return based upon market demand while meeting the sustainability objectives. The target reference point for prawn size is <40 prawns/kg and the limit is 40/kg.
- The management plan (McDonald 1998) points out that fishing prawns at the 40/kg and smaller sizes has "significant potential to impact on the spawning biomass through overfishing of recruits to the fishery". However, there is also potential to induce recruitment overfishing by premature intensive harvesting of aggregations of large potential spawners.

The target reference points for effort are based on effective days, which are a function of the nominal days, trawled multiplied by the fishing power of the fleet. The virgin biomass exploitation is the proportion of recruits to the fishery, which remain to spawn following depletion from fishing. The recruitment index according to MacDonald (1998) is an index derived using the number of recruits/hr trawled where recruits are defined as prawns <35 mm CL. However, the index is best based on the square root transformed mean/nm trawled. The target reference point or target index adapted in this report is a geometric (square root) transformation of the numbers of prawns (males less than 33 and females <35 mm CL) per nautical mile trawled.

Annual trends in prawn catch and nominal effort from 1978/79 to 2000/01 show that the nominal trawl effort (hours) decreased from 46,000 to 19,800 with high catch levels maintained in recent years even though there was a substantial reduction in nominal effort (Figure 2).

3. NEED AND DESIGN STRATEGIES OF THE PRAWN DSS

Management decisions have to be made quickly. Targeted surveys are conducted at pre-determined locations over 1-3 days prior to commercial fishing. The stock size, size of prawn's captured and levels of stock depletion are monitored on a daily basis using mobile phone technologies, facsimile and email thereby allowing direct information exchange from vessel to shore and vice-versa. Owing to the dynamic nature of the stock (eg. movement of sub-optimal size prawns into fishing areas, high depletion of spawners) there is a need for the fleet to respond to real time changes in harvest strategies, which are broadcasted to the fleet by a radio base situated in the main port at Wallaroo. The fleet work in the night with information exchanged over night or early morning. The real time management system is in collaboration between Government (PIRSA/SARDI) and industry to ensure fishing operations are sustainable and economically efficient. The system utilises trawl survey data, information from a committee at sea, and modelling to determine optimum utilisation of the resource. A coordinator at sea has an important role in discussion and communicating information to the fleet and coordinating operations with shore-base maintained by a PIRSA/SARDI fishery scientist who develops harvest strategies in collaboration with the Committee at Sea and the FMC.

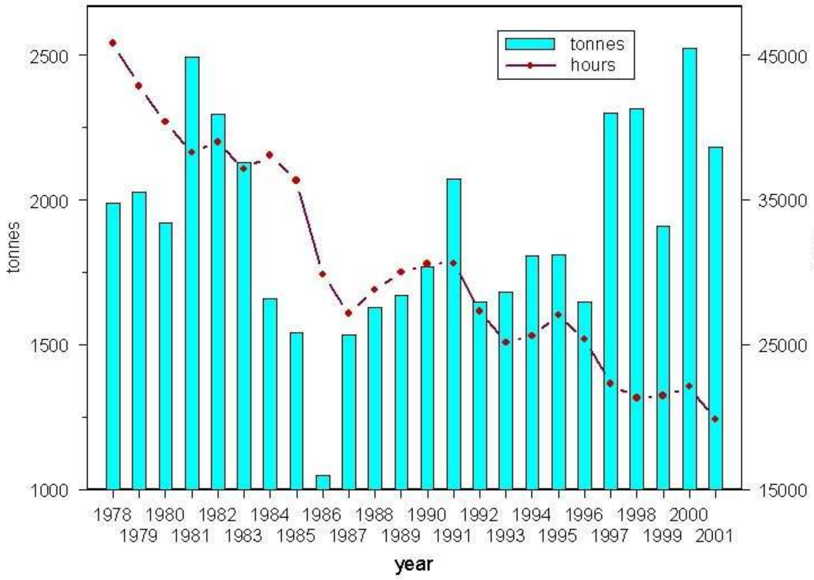

Figure 2: Historical trends in Western king prawn catch and nominal trawl effort (hours) in Spencer Gulf from 1978/79 to 2001/2002

The DSS provides a powerful tool for management of the fishery as information obtained in real time can be evaluated and subsequently discussed at FMC meetings.

The key objectives of the DSS are:

- To allow rapid information processing
- To develop a link of spatial and non-spatial data with statistical analysis software, visualisation and communication tools
- To allow fast analysis of ishery commercial logbook data and assess spatial and temporal pattern in catch and effort
- To improve catch sampling and stock assessment by efficient information communication and improve analytical techniques
- To allow comparison with historical harvesting strategies

The key aspect of DSS is to allow instantaneous evaluation of real-time survey data through spatial visualisation and a statistical comparison with historical data. Visualisation is extremely important due to the multitude of error sources in the handwritten raw data that is sometimes collected under very difficult conditions (i.e. rough sea). Both the visual analysis and the objective statistical evaluation will help management decisions to be made more objectively because they are based on the vast amount of knowledge and information from historic harvesting efficiencies and research projects.

A further intention of the DSS is a long-term influence on the collection of data by suggesting changes to the data collection process. Technological means exist for streamlining the reporting process but implementation may be limited by legal as well as logistic constraints.

However, the prawn DSS will only be used by a very limited number of people in a few committees (Committee at Sea and the FMC). Therefore, less effort is required for user friendliness. The two key design strategies were

- efficiency and
- comprehensiveness.

Efficiency was maximised by using most advanced database technology (ORACLE), a commercial GIS (ArcGIS) and statistical software packages (S-Plus and GENSTAT). Comprehensiveness was ensured by incorporating government and industry databases and placing much effort on entering historic data applying a very rigid quality control at the level of entering data into the database and by visualising spatial pattern.

Technically, the linkages between the software components of the DSS were kept as simple as possible. Exchange is realised through ODBC (Open Database Connectivity) drivers of the Windows operating system or through text files. The database runs on a laptop and is hence transportable. The DSS will only be used by a very limited number of operators and demands substantial skills including excellent statistical knowledge, GIS skills, and also basic SQL knowledge. Using connectivity rather than hard-wiring features is most advantageous for spatial data visualisation and statistical operations, since the operator is able to use a wide range of his favourite tools from a rapidly changing developing software market.

4. APPLICATION OF THE DSS FOR ADAPTIVE REAL-TIME MANAGEMENT

The data collection system incorporates information from stock assessment trawl surveys and adaptive surveys (also called "spot surveys"), which are undertaken to assess the stock and improve the development of harvest strategies. The "spot" surveys are smaller research surveys undertaken over limited areas prior to the commencement of fishing in each period with independent research observers required to record catch and prawn size at strategic locations determined by research in collaboration with FMC members.

The main stock assessment surveys provide vital information on stock, as well as develop harvest strategies. Information on biomass density, levels of recruits and the abundance of spawners are required as a feedback and adaptive control system, especially when depletion is high. Furthermore, size frequency and prawn density data from different regions (assemblages of trawl stations) are used to simulate optimal harvest periods to optimise egg production and economic return. Spatial harvest simulation models have been developed and incorporate a suite of input parameters including: prawn size frequency, densities, natural mortality, fishing mortalities, size-fecundity and maturation, seasonal catchability, growth parameters, and price structure.

Once data are obtained from surveys, simulations are done to determine the optimum period to fish different areas. Figure 3 shows an example of the information processing and statistical modelling. Based on sampling in February 2002 the bio-value ($/hr trawling) of a section of the Wallaroo ground would maximise value in May 2002, (Carrick 2002).

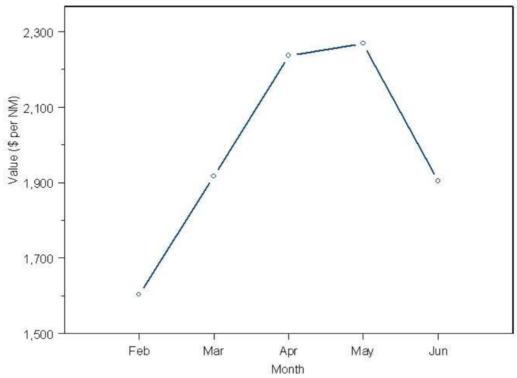

Figure 3: Simulation of optimal period to harvest a segment of the Wallaroo prawn stock from survey sampling undertaken in February 2002

The difficulty of using historic information in the database with newly collected data in statistical models implies that users of the DSS need to be highly experienced and skilled. Data are heterogeneous and the assumptions of the statistical models need carefully evaluated, which is best accomplished within statistical software packages rather than having statistical procedures hard-wired in a DSS.

Throughout a fishing period, areas available to fishing can change as fishing progresses. Therefore, fishing areas are opened and closed based on the size of prawns, catch rates, depletion, spawning status and likely migration patterns of prawns. A key feature of this fishery is the use of real time monitoring and the corresponding changes to fishing strategies throughout the fishing periods in response to the daily movement of prawns and fleet depletion rates. Effective communication of "real time" information is critical to ensure that management is conducted in a sustainable way. The skippers of vessels have a major role in reporting real time information and a Committee at Sea assist in the development of harvest strategies. Fishery closures are an important "input" tool when orchestrated with effective real time adaptive management. The types of closures in Spencer Gulf consist of:

- Permanent area closures - to protect small prawns and vulnerable discards.
- Seasonal area Closures - variable and are used to protect small prawns, prevent reproductive depletion, and optimise value of catch for different levels of recruitment and stock size.
- Total Gulf seasonal closures - December to March and June to November. To reduce trawl effort and to protect spawners.
- Total Gulf moon closures – to reduce fishing inefficiency and maintain quality of catch.
- Daylight closures – to reduce fishing inefficiency and further reduce impact of trawling on discards and habitat.

A map illustrating the main spatial closures, implemented from April to June 2002, show that a sector of the Wallaroo ground was closed to trawling, owing to prawn size in the closed region being below optimal harvest size (Figure 4).

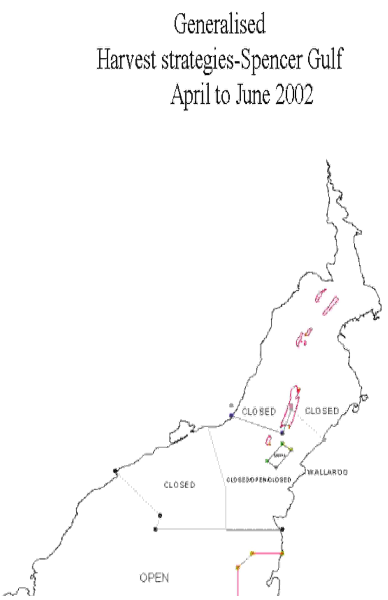

Figure 4: Main spatial closures implemented in Spencer Gulf prawn fishery over the period April to June 2002

5. CONCLUSIONS:

Decision making of the prawn industry has been much enhanced through the development of a comprehensive database that constitutes the heart of the DSS. Of lesser importance for the management of the industry has been a comfortable user interface. Two data sources are most important: catch and effort and targeted surveys. The data is collected as part of the mandatory reporting of catch and effort. Most likely, without the regulations formulated in the 1982 act we would not have such a comprehensive database. Yet the main deficiency of the mandatory data collection (catch averaged per day) is the lack of spatial reference. Location of best fishing grounds and risks is proprietary individual fishermen knowledge that is not readily shared. It may be assumed that the biggest hurdle for further advances in management is the lack of evidence that information sharing will increase individual fishermen income.

The industry is sustainable and the autonomous decision making of the industry has not been harmful to the stock as this can unfortunately be readily observed in other fisheries. This can be attributed in part to the small and regionally isolated community of fishermen with a common interest in maintaining the productivity of their assets over the long term. In fact, a majority of the industry steering committee members has historically been advocating a reduced fishing effort and extent. The DSS provides objective arguments. An important aspect of the prawn fisheries, however, is the increase of the price with prawn size; hence economic return can be increased in spite of a reduced catch thereby contributing to the health of the industry.

6. ACKNOWLEDGEMENTS

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