Modelling Prawn Movement and Spatial Dynamics in the Spencer Gulf and West Coast Prawn Fisheries.

Neil A. Carrick and Bertram Ostendorf

FRDC Project report 1999/142

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1.1 Objectives

The key aspect of this project is the development of a comprehensive database enabling an 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 objective statistical evaluation will increase the objectivity of management decisions as they are based on a vast amount of knowledge and information from historic harvesting efficiencies and research projects.

The development of the database will, in turn, influence 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. Part of this project is to refine the commercial logbook data system to assist PIRSA Fisheries in developing the management plan for the prawn fisheries.

The specific objectives are:

1. To develop a spatial database that links closely with GIS (geographic information systems) and statistical analysis software.
2. To plot prawn tag recaptures and model growth and movement patterns using dynamic spatial visualisation techniques.
3. To analyse fishery commercial logbook data and model spatial and temporal pattern in catch and effort.
4. To improve catch sampling and stock assessment by efficient information communication and to improve analytical techniques.
5. To develop and test the real-time electronic data transfer of information relating to management.
6. To document and map historical harvesting strategies.
7. To analyse, document and publish significant field research undertaken in the past.

1.2 Outcomes

The project has contributed to:

a) The sustainability of the fishery through the understanding of spatial and temporal processes of prawn populations and the development of sustainability indicators and performance measures for the Spencer Gulf and West Coast prawn fisheries. The results have been used for an application to Environment Australia (EPBC Act 1999) for the ecological assessment of the prawn fisheries;

b) The goal of maximising the economic efficiency of the Spencer Gulf and West Coast prawn fisheries, and

c) The development of tools for the electronic transfer of data with the potential to lead to significant gains in the accuracy and efficiency of data collection systems and data analyses, as well as reduced research costs.

The project demonstrates that co-operative research and management programs with industry can be successful and cost effective. Adaptive management experiments have been used to improve the understanding of spatial processes in the Spencer Gulf prawn fishery and applied to management. An integrated spatial database system has been developed for the Spencer Gulf and West Coast prawn fisheries. Research and applied management resulted in substantial economic gain (>$100m) by developing spatially explicit harvesting strategies that maximise the value of catch, decrease the costs of fishing and minimise the risk of recruitment decline. The main outcomes of the research are:

1. Improvements in the management and research of the fisheries through a greater understanding of spatial processes and dynamic changes in the fisheries and the development of: (*i)* an integrated spatial database for research and management based on fishery-independent trawl surveys, commercial catch and effort data, fishery monitoring and tag mark-recapture data; and (*ii)* methods for analysis, simulation modelling and visualisation (including mapping) of research results (fishery-independent trawl survey, prawn movement and commercial catch and effort data) and harvest strategies (e.g., closures).
2. Enhancement of methods for assessment of the fishery sustainability indicators and the influence of environmental variation on recruitment. Research in the fisheries has resulted in the development of risk-averse harvest strategies and models for the minimization of stock decline.
3. The research showed that the relationship between prawn abundance and catchability (q) was not constant, which has important implications for the use of commercial catch and effort data for stock assessment and monitoring of the Spencer Gulf prawn fishery. That is, catch-per-unit-effort (CPUE) can result in a biased and an overestimate of stock size. Hence, there is a need to ensure that fishery-independent surveys continue over the long term for stock assessment. There is now sufficient data to rationalise survey objectives and streamline processes for cost-reduction.
4. Increased fishery profitability through the development of harvest strategies which optimise the value of catch. Research has shown that the development of harvest strategies based on objective harvest simulation models which incorporate trawl survey data has resulted in substantial economic gains to the fishery through an increase in trawl value ($/h trawled) and fishery sustainability. For example, a decision to target fishing operations at an important fishing ground (Wallaroo) in April 1998 rather than March 1998 resulted in >$3.5m increase in harvest value. Research has demonstrated that strategic delays in harvesting different spatial units of the stock result in significant increases in both value of production and egg production.

1.3 Non Technical Summary

This report contains information on the database systems developed by the project, focusing on resource sustainability and improvement of fishery management. The report describes a spatial database developed in Oracle and its application to stock assessment, and the real-time management of the Spencer Gulf and West Coast prawn fisheries. The research documents major changes that occurred in the Spencer Gulf prawn fishery from 1977 to 2003 and resulted in substantial economic gain through adaptive harvest strategies. The report outlines the collapse and recovery of the West Coast prawn fishery and the influence of the environment and spawners on recruitment. Fishery-independent trawl survey, tag movement and growth and catch and effort logbook data has been extensively used in the development of harvest strategies that require a detailed understanding of spatial processes including the distribution of abundance and dispersal of the stock. In order to improve stock assessment, a new logbook system was designed and tested which incorporated detailed spatial information data from plotters and commercial grade data. The system provided fine scale information on the spatial distribution of catch and effort and on daily prawn size composition (grades), providing better data for monitoring the sustainability of the fishery. However, there is ample scope for improvement in data collection through more effective electronic data transfer.

Data obtained from large scale fishery-independent trawl surveys provides the main input for a decision support system (DSS) developed for the fisheries. This system links an Oracle database with a geographic information system and commercial statistical packages. Data was obtained from several sources including information collected by industry and government. Fishery-independent trawl survey sampling plans were developed for Spencer Gulf in 1981 and have been refined over time. The survey sampling data collected in Spencer Gulf provides valuable information on spatial and annual trends in prawn recruitment and spawner abundance, prawn size composition, catch rates and trawl value for >200 sampling sites, with over 60 000 prawns measured for each stock assessment trawl survey. Further, over 100 000 tagged prawns were released from 1986 to 1990 with >10 000 recaptures, facilitating the modelling of growth and movement of prawns. Tag mark-recapture results demonstrate that *M. latisulcatus* has a lifespan exceeding 3 years, is the longest recorded for a penaeid prawn. Prawns have been shown to have 2 main net movement patterns which reflect two meta-populations. The first is a strong net movement from north to south and for the second, prawns generally move in a south-west and north - west direction. The third data source is based on commercial catch and effort data and fishery monitoring information. It includes archived closures and harvest strategies as well as information on vessels for the estimation of effective effort. Furthermore, environmental data was included into the system (sea level height, bathymetry, sea surface temperatures from loggers and satellites). The trawl surveys provide information on prawn abundance at areas which are closed and open to fishing, and are used with commercial catch and effort data for stock assessment and management of the fishery. The system enables the generation of quantitative data including information on: biomass and density of prawn stocks, spawners and recruit abundance, population fecundity, prawn size composition (size frequency and grades).

Major changes in spatial pattern of production have been documented for Spencer Gulf between 1977 and 2003. Trawl effort decreased from 1977 to 2003 with >250 days fished in 1977 compared with 55-60 days in recent years. Production was stable from 1986-87 with record catches exceeding 2 300 tonne in 1998-99 and 2000-2001. The average size of prawns landed increased from 1977 as evident from processor grades and field monitoring. For example, the proportion of smaller prawns landed (i.e., >20 prawns/lb, head-on) fell from 42% to 3% from 1978-79 to 2001-02 with a commensurate increase in larger grades from 29% to 73%. Hence, production value has largely increased as higher premiums are attributed to larger prawns, supporting the benefits of adaptive harvest strategies. Real-time abundance and size data from trawl sampling surveys was used in conjunction with derived fishery parameters and price structure ($/kg) information to determine the optimum time to fish different spatial units of the stock. Simulation models were developed to predict optimal harvest periods for maximising trawl value ($/h). The simulation using real-time data showed gains in trawl value >90% due to gains in growth exceeding losses to natural mortality and through prawn movement dispersal. A conservative estimate of $3.5 million in production value arose by adaptation of a spatial closure at Wallaroo in April 1998. Harvest strategies were developed in conjunction with PIRSA Fisheries and industry, resulting in substantial economic gain to industry by optimising the value of catch. Furthermore, harvest strategies have been conservative over the last decade, especially in 2003 where a significant decline in recruitment to prawn grounds was detected. The latter was reported in real time to industry and Government, with constraints on trawl effort (and exploitation levels) implemented by Government in collaboration with industry.

For the first time, a spawner-recruit relationship (SRR) was determined for the West Coast prawn fishery. Prawn recruitment variation in the West Coast prawn fishery was found to be influenced by sea level height (SLH) and the study provides evidence that ENSO (El Nino southern oscillation) events influence recruitment strength in the oceanic West Coast prawn fishery. The visualisation of results is most important for effective communication with industry. Dynamic animation of prawn movement and spatial data mapping (recruits, spawners, catch, effort and closures) using GIS software provided industry and management with a greater understanding of stock dynamics and of historical changes in the fisheries. A web site is being developed to promote the research as a source of information for industry and as an information transfer tool (e.g., closures, survey results) from vessel to shore and vice versa using mobile phone technologies(CDMA).

Studies of prawn abundance distribution, prawn dispersal and spatial depletion patterns have shown that delayed fishing strategies have proved beneficial by increasing fishery profitability and sustainability. The development and implementation of adaptive harvest strategies have resulted in substantial economic gain (>$100m) to the Spencer Gulf prawn fishery, mainly through an increase in the value of catch and fishery sustainability. Fishery-independent surveys were used to assess the economic and biological benefits of keeping a major region (Wallaroo) closed to fishing from January to April. Case studies are provided which show that premature harvesting at Wallaroo from February to April prior to 1998 resulted in lower catch value, created problems in spreading the fleet in subsequent harvesting periods and reduced potential egg production from spawning in the February to March period. Hence, the research results underpin a process for improved management. Distribution of prawn abundance, trawl value and size grades change largely from February to November due to movement dispersal, growth and fishing. Fishery depletion studies showed that catchability (q) increases non-linearly with stock size (and area available to fishing). Hence, CPUE is a biased estimator of abundance when a conventional catch-equation theory (constant q) is applied to assessments. The research provides evidence of a negative relationship between prawn stock size and CPUE which can be considered as a depensatory density-dependent process. The use of CPUE as a gauge for stock size can result in an overestimate of stock.

The research and management of the fishery are dependent on obtaining quality data; this can only occur with industry playing a major role in both the research and management process.

Keywords: ***Melicertus latisulcatus*, spatial processes, adaptive management, stock assessment, sustainability, Oracle database, spawner-recruit relationship, biological reference points, decision support**

1.4 Benefits and Adoption

The FRDC project enabled the assembly of substantial data from fishery-independent surveys (from 1981-2003), prawn tagging and historical commercial catch and effort data into an integrated Oracle database system. The database has largely facilitated statistical modelling and Geographic Information System (GIS) studies, resulting in a greater understanding of the fishery spatial processes and better management of the fisheries.

The integrated Oracle database system, analytical procedures and software developed by the project have provided significant benefits to the South Australian prawn fishing industry, management and research. industry has gained by increased fishery sustainability and profitability through applied research focused on spatial processes. The database system and the linked statistical modelling and GIS will allow information (survey results, historical maps of catch and effort, prawn size and closures etc) to be downloaded by fishers from a web site (spgprawn.com) developed to promote research results and for the electronic communication of information. With further development, real-time data from surveys and catch and effort data from fishing operations can be uploaded by fishers and sent to the web site for rapid analysis and visualisation of results. A major benefit to fishers has been the demonstration that the electronic data transfer from shore to vessel and vice versa is a powerful tool for transfer of information involving industry actively in the research and management of the fishery.

Further work will result in substantial benefits to industry in efficiencies and reduced costs (e.g., recording data on forms and data entry), extended knowledge and greater understanding of the research and management process. The work could potentially be transferred to other fishing sectors in South Australia and interstate.

The project has provided research and management with powerful tools for assembling, analysing and “picturing” complex spatial data. Electronic data transfer, from ship to shore and vice versa, using CDMA was tested using simple survey and commercial catch and effort data and found to be efficient and cost effective. Systems were developed for large spatial data, resulting in the rapid data assembly and analysis required for management meetings held 6-8 hours after fishery-independent trawl surveys were completed. Appendix 1 shows a general fisher log entered in an Excel spread-sheet and downloaded to a central server. As part of the project, a new logbook system was devised and a new database system was developed by the author in collaboration with industry and used in this project (Appendix 2). A key application of the database with auxiliary information (eg. maturation and spawning) resulted in the development of an objective and conservative harvest strategy for Spencer Gulf over the November/December 2003 period, which proved successful (Appendix 3).

1.5 Further Development

The fishery performance indicators require further refinement in the development of sampling strategies to assess recruitment, spawners and biomass density. The definition of recruits needs clarification. For this assessment, two scenarios of recruits were used, namely male prawns <=32 mm CL and females <=34 mm CL and prawns <35 mm CL. Further work needs to be undertaken to define recruit sizes with cohort analysis, incorporating variable recruit sizes to grounds over different spatio-temporal scales. There is a need to optimise trawl sampling plans, which is difficult due to multiple research objectives and spatial differences in the distribution of recruits and spawners. Further research is required in examining risk and decision frameworks relating to biological performance indicators, which would benefit management. Recruitment and spawning stock size are vital parameters for gauging the "health" of the fishery and more attention must be directed to minimising sampling bias.

The use of mean prawn size as a performance indicator based on commercial grade data needs to be addressed. The population consists of a large range of sizes (mixed cohorts) and there can be large differences in sex ratios over time and space. The development and refinement of improved statistical tests based on size distributions are required. The results presented on distribution tests using maximum likelihood are the first published for a penaeid fishery and the method requires refinement in model application and more extensive field data. Further refinement of size distribution estimates of landed catch is expected to occur in the future by operators increasing the number of size categories. Sub-sampling of size of the sexes over grades and fishing periods could be undertaken to enhance estimates for the separation of sex and sex ratio differences. More comprehensive size data would result in greater precision in the estimation of the size composition of catch and exploitation. It is important to note that grading data in Spencer Gulf should not be used to derive recruitment indices because factors such as harvest strategies and target sizes may differ between years.

A priority focus of research in Spencer Gulf and the West Coast fisheries should be the development of spawner-recruit (SR) and recruit-spawner relationships and the examination of the effects of environmental variation on recruitment. Additionally, substantial data has been collected on juvenile prawn populations and this data needs to be integrated into the Oracle database to determine the relationships between juvenile recruitment strength, recruitment to grounds and the influence on fishery production. Hence, the development of an integrated database system incorporating juvenile prawn population studies would facilitate the prediction of recruitment and production and could be used as a feed-back control system in adaptive management.

Extensive data has been collected on female maturation/spawning, spatial abundance and population structure, growth and movement in Spencer Gulf, Gulf St. Vincent and the West Coast. As above, this data needs to be integrated in order to compliment stock assessment and management of the fisheries. Most importantly, data can be used to develop harvest models which would assist in making well-informed decisions regarding harvest strategies for the fisheries, especially if real-time information on prawn size and the spatial distribution of abundance are used as a fishery management tool.

Substantial improvements in cost efficiency can be made by adopting faster data collection/management decision cycles using electronic data transfer. Electronic data exchange and reporting systems can substantially reduce the need for error-prone handwritten forms and results in a much faster turnover. The current database, in conjunction with off-the shelf technology (i.e. CDMA), is a solid basis for the further development of electronic data transfer from vessel to shore and vice-versa. It is technically possible to collect large complex data in real time, which will allow predictions of spatial abundance and prawn size composition and prawn movement because data can be evaluated relative to historic data in the database. This in turn can be used with optimisation algorithms to refine harvest models and predict the best harvest strategies.

Knowledge is limited about how South Australian fisheries interact. Particularly prawn, blue-swimmer crab and southern calamary fisheries (among others) have previously been treated in isolation and there is a need to integrate data collected from fishery independent surveys, field experiments across fisheries. As an example, the joint knowledge base that has been accumulated for the fisheries could be used in a systematic way with potential benefits for each fishery. Blue crabs can cause a value loss for prawn fisheries of up to 30%, which might be reduced if the spatial distribution of crabs was known. The direct benefits for crab and calamary fisheries would be the provision of spatial population data, which would improve stock assessment and harvest efficiency. Furthermore, large numbers of small calamary are captured and discarded at sea and distributional information collected during fishery independent prawn surveys would be valuable for calamary stock assessment and management.

The availability of remote sensing data at a high spatial and temporal resolution is rapidly increasing. Remote sensing techniques allow the assessment of fundamental conditions affecting prawn populations such as the health of the prawn breeding grounds or the availability of warm water and nutrients for the primary food chain (i.e. temperature, chlorophyll). Such data could be included in our models, improving the spatial and temporal prediction capability of the potential prawn growth and recruitment strength.

In summary, the priority research needs which have been identified are:

1. Development of an integrated database for all three South Australian prawn fisheries (Spencer Gulf, Gulf St Vincent and West Coast) incorporating extensive data on prawn maturation/spawning, movement and growth and spatial abundance patterns and environmental variation. Comparison of seasonal growth patterns across fisheries and development of harvest models for the fisheries.
2. Improvement of electronic data transfer and database systems for real-time adaptive management and fishery performance indicators.
3. Integration of extensive inshore juvenile prawn population data, nursery environmental and female maturation/spawning data collected in the past into the database developed for the Spencer Gulf prawn fishery.
4. Enhancement of mathematical modelling and stock assessment methodologies for the Spencer Gulf and West Coast prawn fisheries.
5. Enhancement of environmental data collection systems for real-time data transfer from the fleet, remote data loggers and remote sensing techniques. This would improve the modelling of spawner-recruit relationships and the understanding of the influence of environmental variation on recruitment and fishery production.
6. Quantification of prawn vulnerability (availability) for improved stock assessment and fishery modelling. The effects of season (month), moon illumination, tide and water temperature are expected to influence prawn burrowing and emergence behaviour (availability). Hence there is a need to quantify these effects through field depletion experiments and field aquaria studies.
7. Integration into the Oracle database system of extensive data on bycatch which has been collected during fishery independent trawl surveys and through field experiments in Spencer Gulf.
8. The results have highlighted a need for additional mark-recapture studies focused on obtaining vital information on movement patterns. Tag release-recapture data provides a powerful tool for the development and monitoring of harvest strategies.

1.6 Planned Outcome

The outcome of this project is to support fishery management in an objective, quantitative way. Statistically sound spatial data is collected in real time to assess the actual spatial pattern of prawn population parameters. Decision support is based on a comprehensive set of historic fishery-dependent and independent data and scientific knowledge.

1.7 Intellectual Property

Based on the relative value of contributions the share of intellectual property arising from the work is 37% for FRDC, 33% for The University of Adelaide, 17% for PIRSA, and 13% for the Spencer Gulf and West Coast Prawn Fishermen's Association (SGWCPFA).

1.8 Acknowledgements

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1.9 Project Staff

Neil Carrick (Adelaide University)
Bertram Ostendorf (Adelaide University)
Rowan Hosking (Oracle database programmer)
David Craig (contract technical services)
Greg van Gaans (ESRI)
Laurie Pullman (Pullman Computing)

2 Background

2.1 Spencer Gulf and West Coast prawn fisheries.

There are three prawn fisheries in South Australia, Spencer Gulf, Gulf St Vincent and the West Coast, all of which are based exclusively on the western king prawn (Figure 2.1).

The Spencer Gulf (SG) prawn fishery is a single species fishery based on the western king prawn *Penaeus latisulcatus* (Penaeidae). Recently, the systematics of Penaeidae were revised and the subgenus of Penaeus was raised to the generic level of Melicertus (Perez Farfante & Kensley 1997). The species name is accordingly *Melicertus latisulcatus*. A smaller penaeid, *Metapenaeopsis crassima,* occurs in SG but is of no commercial value and is not landed.

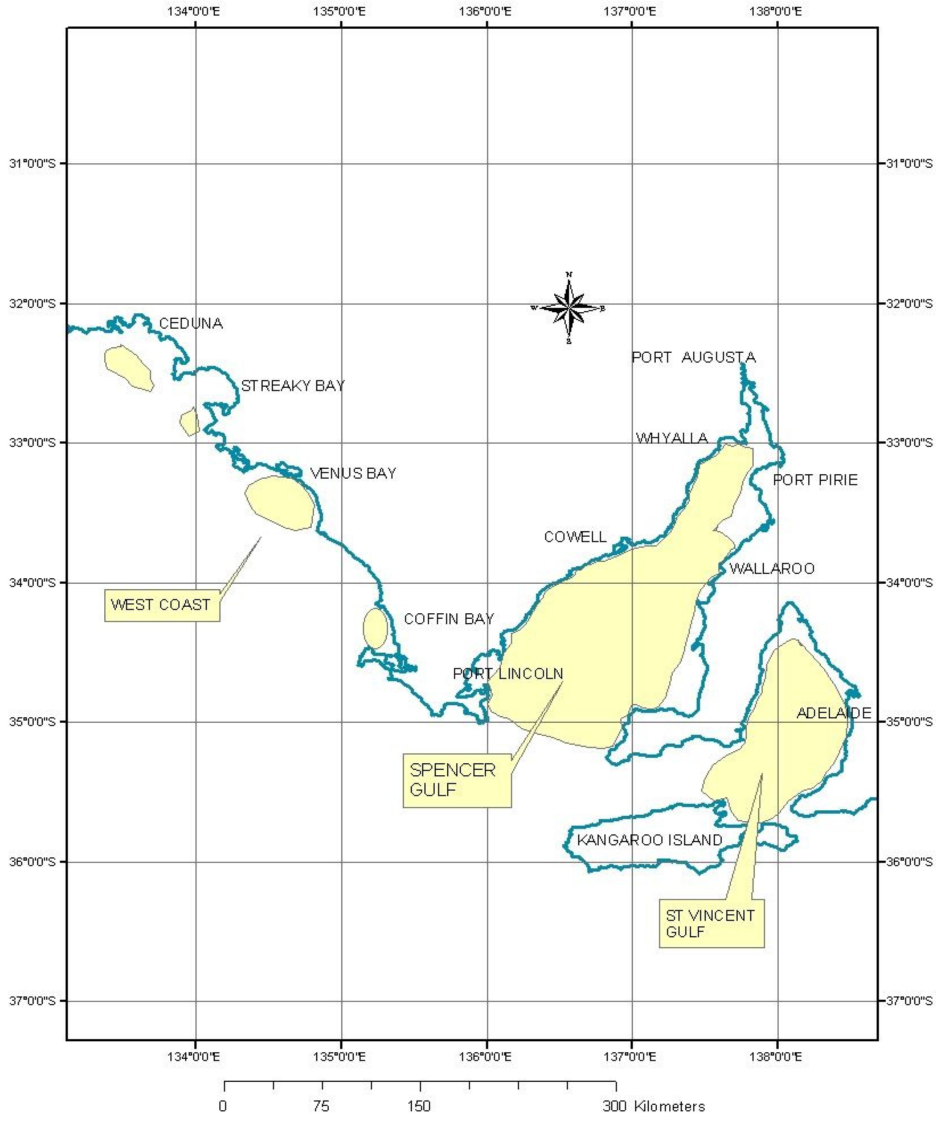


Figure 2.1: Geographical location of South Australia's prawn fisheries.

There are 39 commercial fishery licences issued for SG. Average annual catches for the Spencer Gulf fishery is in the order of 1,800 tonnes. Fishing is permitted in all waters of Spencer Gulf north of the geodesic joining Cape Catastrophe (Latitude 34º 35.4'S, Longitude

136º 36.0'E) on Eyre Peninsula and Cape Spencer (Latitude 34º 9.6'S, Longitude 135º 31.2'E) on Yorke Peninsula. Trawling normally does not occur from late December to March or from mid-June to November, each year. There are nine main trawl regions in SG (Figure 2.2). They are referred to as:

1 Northern area (Whyalla to Wallaroo).
2 Wallaroo
3 Shoalwater
4 Cowell, Arno Bay and Western Gutter
5 Main Gutter
6 Wardang Island
7 Southern Gutter
8 Corny Pt
9 Thistle Island and Rosalind Shoal

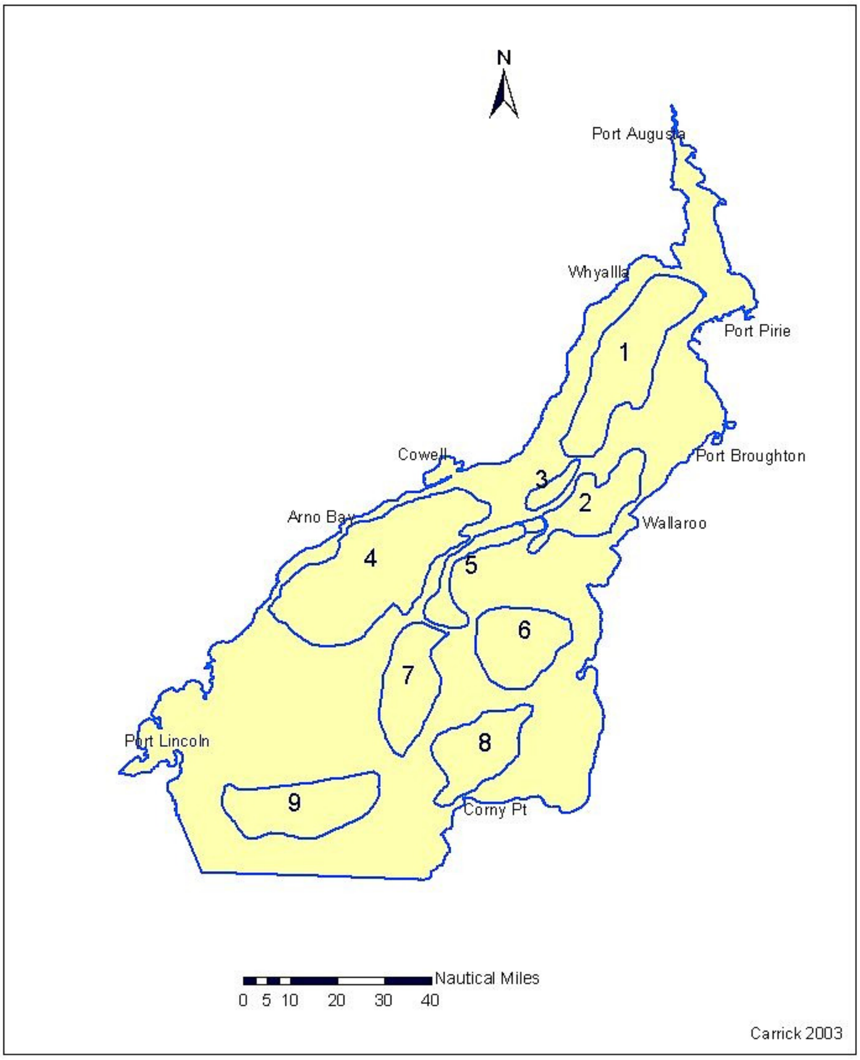


Figure 2.2: Geographical location of main trawl grounds in Spencer Gulf.

The West Coast prawn fishery is an oceanic penaeid fishery situated between Coffin Bay and Ceduna (Figure 2.3). There are 3 main prawn trawl regions, referred to as Venus Bay, Coffin Bay and Ceduna & Olive Island.

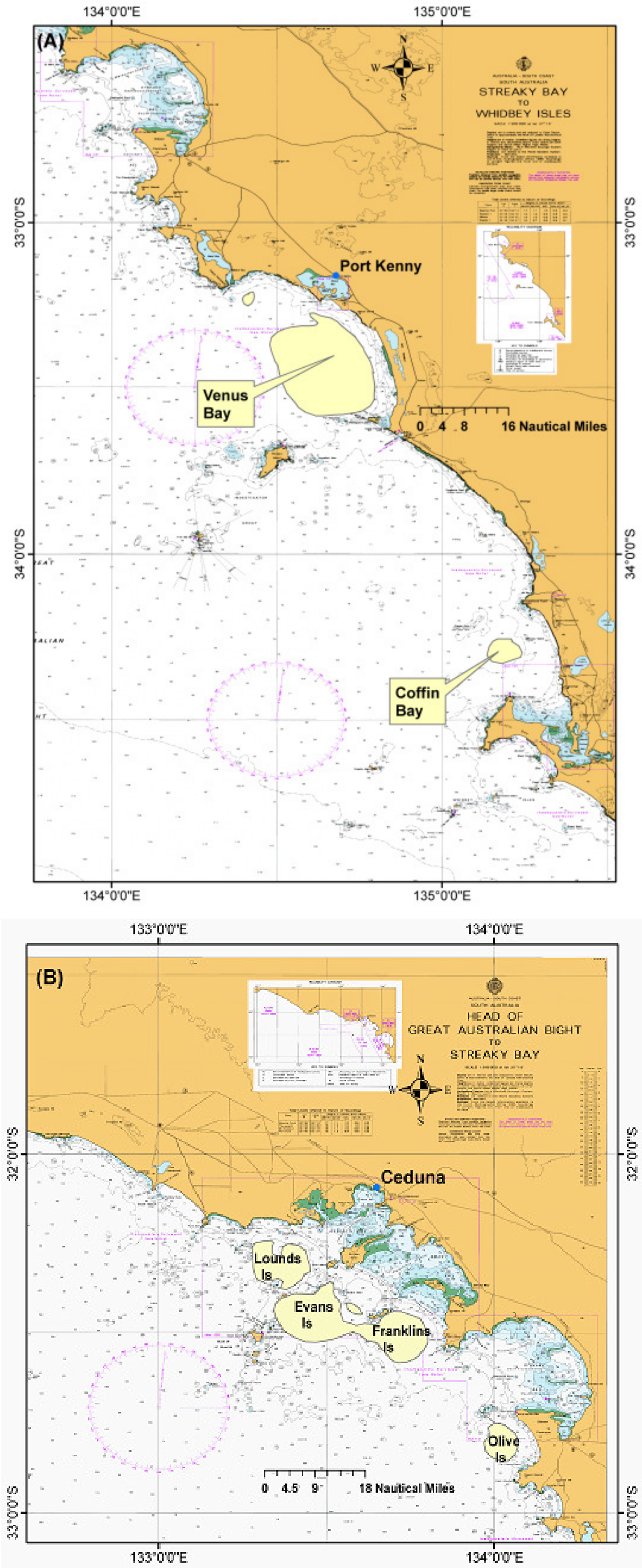


Figure 2.3: Location of West Coast prawn trawl grounds, (A)-Venus & Coffin Bay; B - Ceduna and Olive Island region.

2.1.1 The bathymetry of Spencer Gulf

The Spencer Gulf is a hyper-saline embayment. The bathymetry (Figure 2.4) and sediment regime of the Gulf have strong influences on trawl operations. Trawling does not take place on hard bottom "reef' structure but on soft bottom habitats. Most trawling in Spencer Gulf takes place in waters less than 15m deep with trawling prohibited in depths less than 10m.

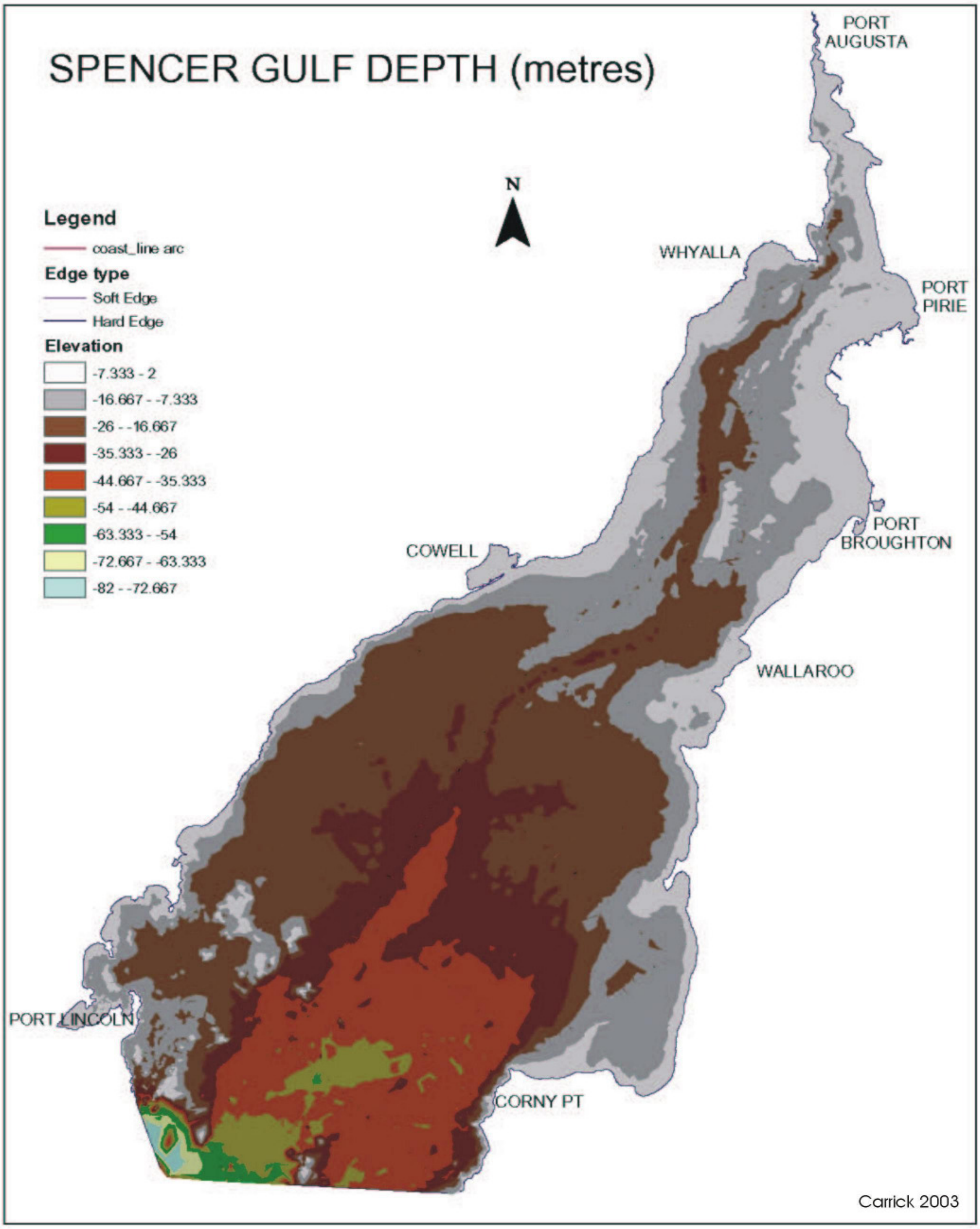


Figure 2.4: The bathymetry of Spencer Gulf interpolated using water depth (m) data from PIRSA Spatial unit and trawl survey spatial data.

Trawling does not cover or sweep all of the grounds and research has demonstrated that less than 10% of the area of the Gulf is trawled (Carrick 1999, Carrick and Williams 2001, Carrick 2002). There are areas within both closed and open regions that have never been trawled.

A comparison of water temperatures over major Australian fisheries (Carrick 1999) show that temperatures in Spencer Gulf are colder and have a stronger seasonal cycle than in the other Australian prawn fisheries (Figure 2.5). The temperature plots are based on data provided by the National Tidal Facility (Adelaide), CSIRO archives, Western Australian Fisheries Research temperature logger, South Australian Tuna Boat Owners temperature loggers, and a temperature logger which was placed in mid-Spencer Gulf in 1992.

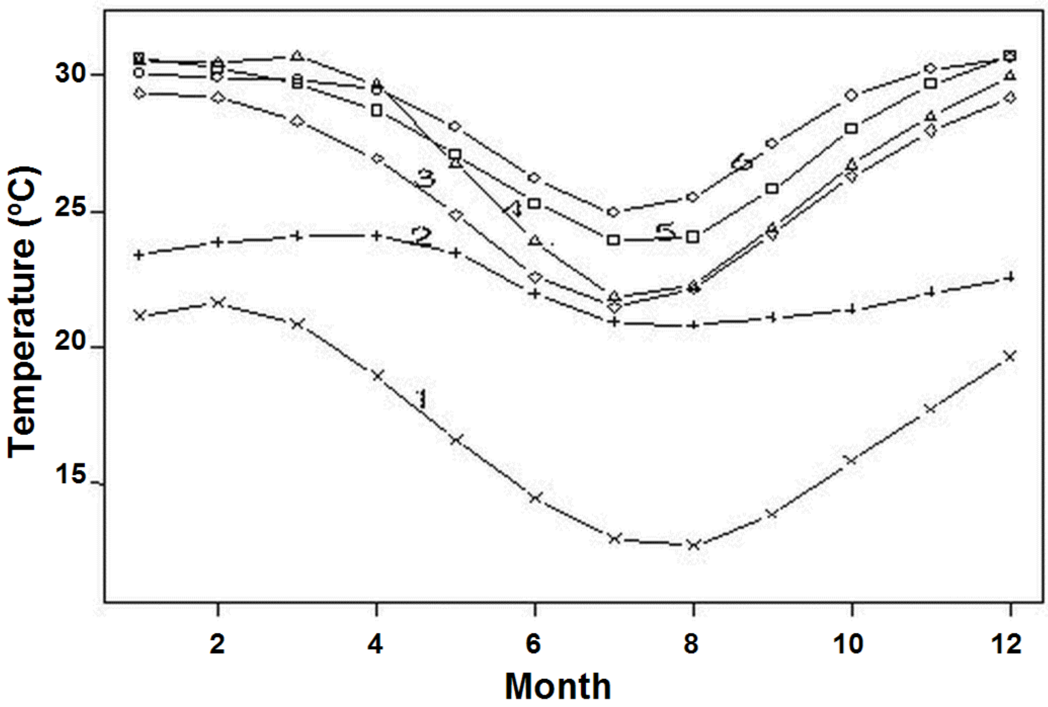


Figure 2.5: Comparison of sea water temperature (ºC) seasonal patterns over main Australian penaeid prawn fisheries (1 - Spencer Gulf; 2 Shark Bay, WA; 3 - Broome; 4 - Cape Ferguson; 5 - Darwin and 6 - Groote), (from Carrick 1999 (a)).

The coolest cycle is in Spencer Gulf, and the second coolest in Shark Bay, Western Australia. The warmer cycles are from north-eastern Queensland, north-western Australia and the Gulf of Carpentaria (NPF).

Water temperature cycles for the West coast prawn fishery are detailed in Wallner (1985) and in section 6.3. Water temperatures over the West Coast grounds differ from Spencer Gulf. West coast water temperatures are colder than Spencer Gulf and rarely exceed 18.5℃ at Venus Bay with marked stratification between surface and bottom layers from January-March when bottom temperatures can be 2.5℃ colder than surface waters. Minimum water temperature occur in September at Venus Bay, with negligible variation between surface and bottom layers (Wallner 1985).

2.1.2 Description of trawl gear and operational practices

Commercial fishing is undertaken at night using the demersal otter trawl technique. This involves towing a funnel-shaped net leading into a bag (or cod-end) over the seabed with trawl boards used to keep the nets open and spread horizontally while being towed (Figure 2.6).

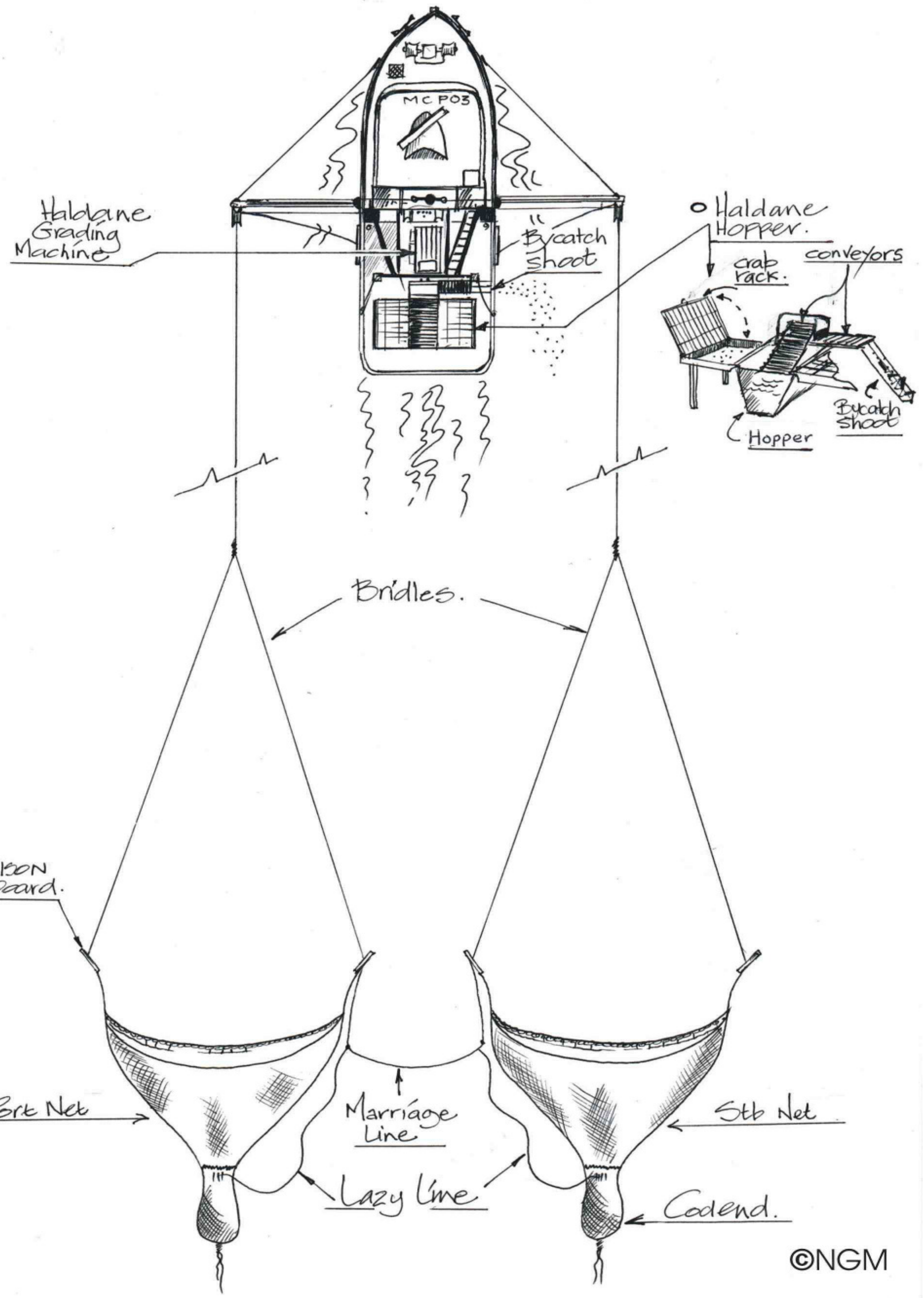


Figure 2.6: Spencer Gulf prawn fishery double rig trawl gear and location of hopper sorting and prawn grading system.

A separate bag, or "crab-bag", is attached to the inside of the cod-end to collect larger animals including blue swimmer crabs and other mega-fauna (e.g., sharks, rays and skates), (Figure 2.7).

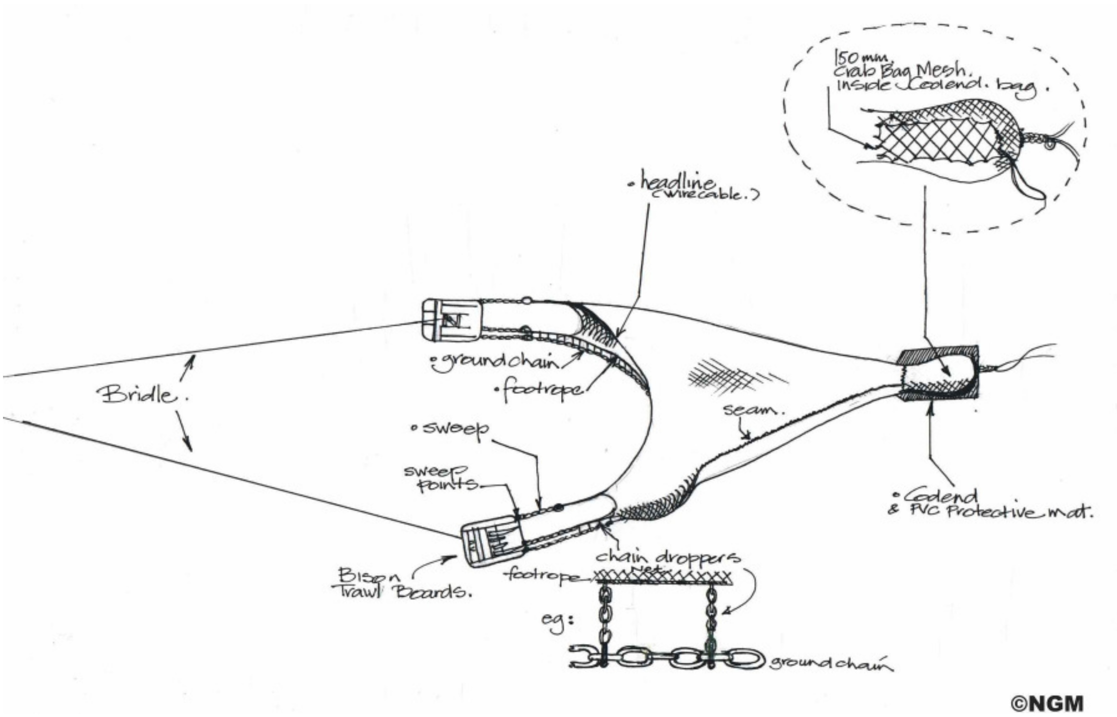


Figure 2.7: Trawl net configuration showing trawl boards, head rope, ground chain and cod end with crab bag.

The crab bag separates the mega-fauna from the prawn catch, with the main cod-end emptied into a large holding tank containing water which is circulated during sorting (Figure 2.8). A rack, mounted on top of the hopper-conveyor system, is used to collect the contents of the crab bag for a rapid return to sea. The contents of the hopper are sorted via a conveyor system which directs the prawns to a grading machine, and the bycatch is rapidly returned to sea via a chute.

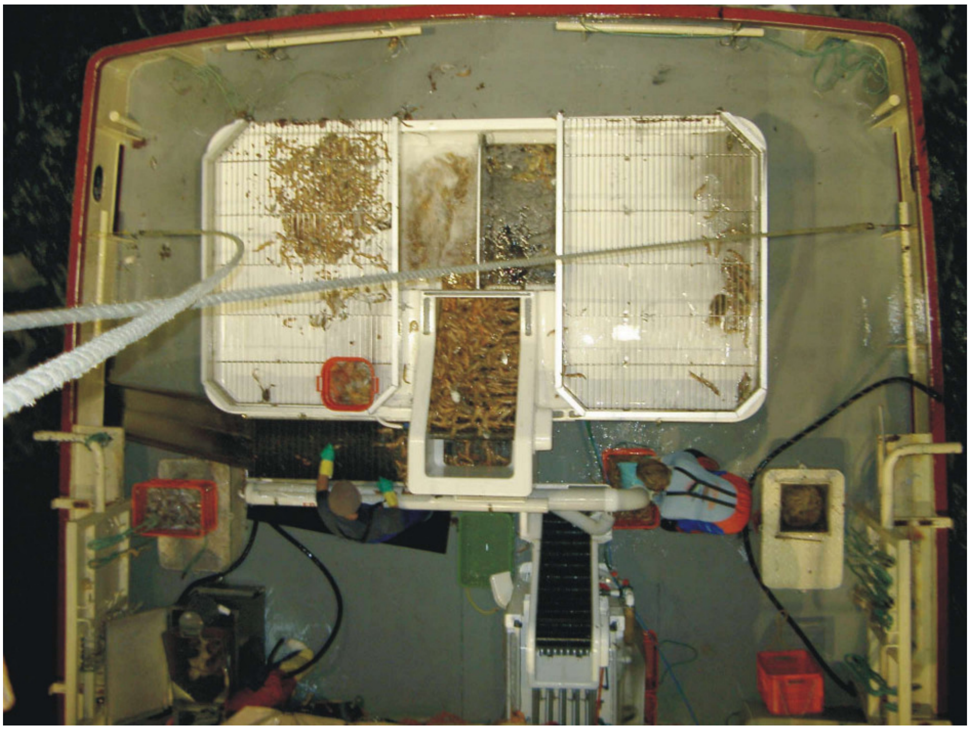


Figure 2.8: View of on-deck hopper/conveyor sorting and grading systems, FRV Roslyn Ann, (image by Cherie Heyes)

2.1.3 Comparison of western king prawn production with other Australian prawn fisheries.

The Spencer Gulf fishery is the largest Australian producer of western king prawn, and is one of 5 Australian commercial trawl fisheries that produce more than 1 500 tonnes per annum (Table 2.1).

Table 2.1: 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	5 – 120
Shark Bay, Western Australia	27	25° 30' S	114° 00' E	1,100 –1,600
Exmouth Gulf, Western Australia	13	22° 00' S	114° 20' E	350-500
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	20-70

*Source: SARDI, WA Fisheries Research and DPIE Canberra.

2.2 Fisheries biology of the western king prawn

2.2.1 Distribution of the western king prawn

The western king prawn, *Melicertus latisulcatus*, is distributed throughout the Indo-west Pacific (Grey, Dall & Baker 1983). Its distribution in South Australia (SA) is restricted to waters of Spencer Gulf and Gulf St Vincent (GSV) and along the west coast in Anxious Bay, Venus Bay and Ceduna. In Western Australia (WA), the species contributes to the commercial and recreational fishery and to a major commercial fishery in Shark Bay and Exmouth Gulf. In the Northern Territory and Queensland, it is a minor species in a multi-species prawn fishery.

2.2.2 Life history and reproduction

The western king prawn has an offshore adult life and an inshore juvenile phase. From spawning, larvae undergo metamorphosis through four main larval stages, termed nauplii, zoea, mysis and post-larvae. The length of the larval stage is dependent on water temperature (Hudinaga 1942), with faster development in warmer water. Larvae are dispersed largely over Spencer Gulf with post-larvae settling in inshore nursery areas at 2-3 mm CL.

Adult female prawns mate, mature and spawn between October and April and it has been demonstrated that there are two main maturation peaks, one in late November/December and another in late January (Carrick 1996).

The male prawn transfers a sperm capsule (spermatophore) to the female reproductive organ (thelycum) and, for successful insemination, the female prawn should have recently moulted. A female prawn can release between 80,000 and 600,000 eggs in a single spawning (Kangas unpublished), with larger prawns producing proportionally more eggs than smaller females. The fecundity–to-size relationship of western king prawns was studied by Penn (1980) using samples collected from Shark Bay, WA. and by Kangas (unpublished) from samples collected in Gulf St Vincent. Data from both studies was analysed by the author to compare relationships between South Australia and Western Australia. The relationship between carapace length (CL) and fecundity is $F = a \times CL^b$. Comparisons of the regression coefficients are detailed below (Table 1.2).

Table 2.2: Comparison of fecundity-to-size relationships of western king prawn populations in South Australia and Western Australia.

Area	a (± se)	b (± se)	t-value of b
South Australia	0.794 (0.006)	3.462 (0.002)	1925.130
Western Australia	0.070 (0.0002)	2.916 (0.001)	2661.940

The relationship between fecundity and size is strong. Non-linear contrasts of the data using an exponential model indicate that the regression coefficient for GSV is larger than for Shark Bay (p<0.005). However, the data is constrained by few samples at the extremes in size, which would bias the results. The size at which females mature has been modelled using field data by logistic regression. The simplest relationship is as follows:

Maturity proportion = 0.0000083 + 1.0/ (1+EXP (-0.277*(mmCL-36.45))

Carrick (1996) found complex relationships between maturity and size over spawning periods and areas in Spencer Gulf. The results were best modelled using a Fourier series model, which indicated that the maturity status of female prawns was highest from 40-45 mm CL. However, further research is needed to address the maturation and reproductive viability of the spawning stock. Preliminary work on female insemination rates has indicated that spermatophore insemination is higher in larger prawns.

2.2.3 Larval prawn distribution

Research by Shokita (1974) found that M. latisulcatus has a larval duration of 2 to 4 weeks. However, this is likely to be dependent on water temperature (Hudinaga 1942). Water temperatures over the main spawning and larval period in Spencer Gulf range from 19-25℃; hence it is expected that the larval period of *M. latisulcatus* could exceed 40 days.

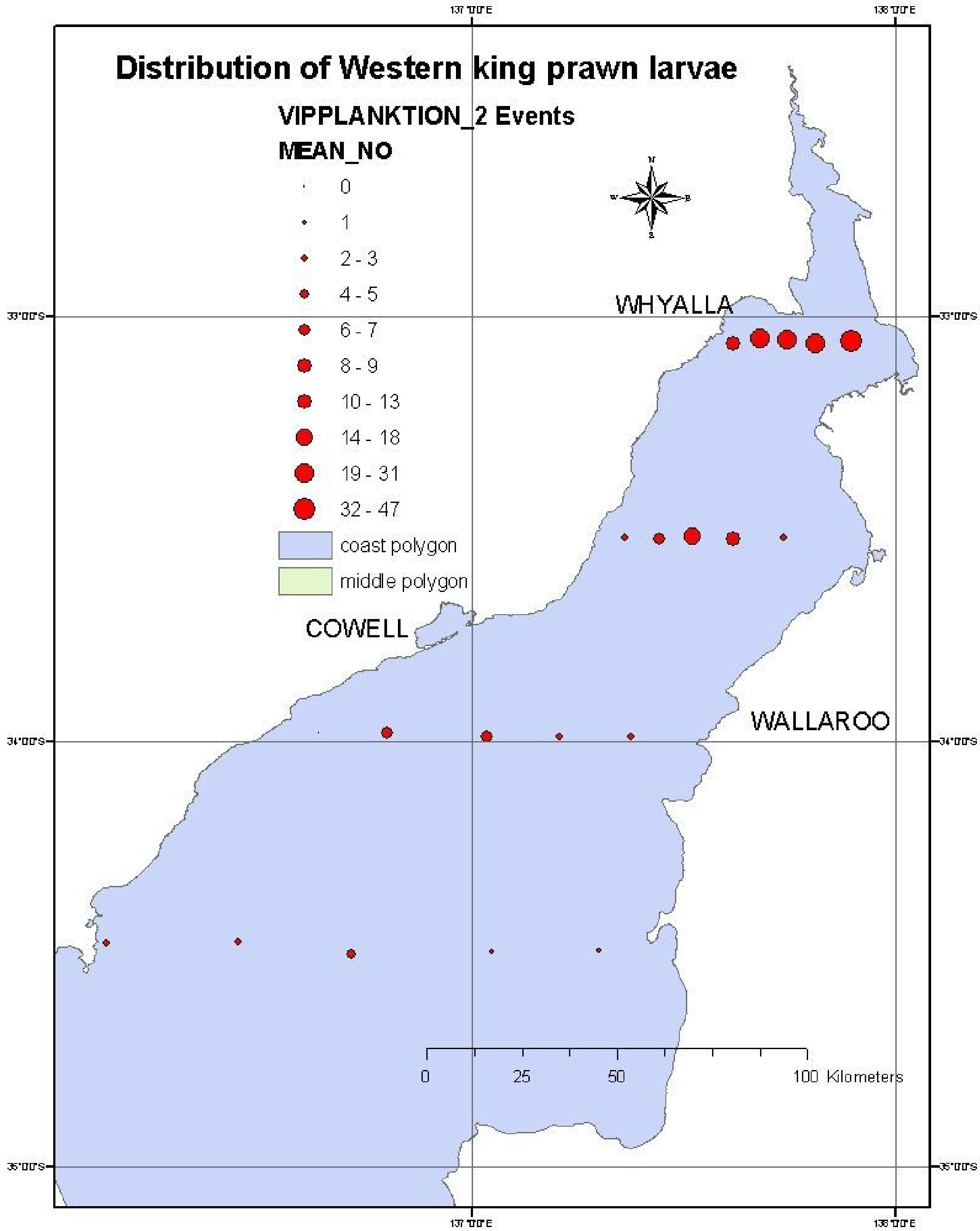


Figure 2.9: Mean numbers of western king prawn larvae (square root number/100 cubic metre) in Spencer Gulf, 1993 and 1994).

The maintenance of a viable prawn fishery is in part determined by the success of the early life history phases of prawns. Although prawn larvae have the ability to move up and down in the water column, they cannot move significant distances horizontally and are generally advected and dispersed by winds, tides and currents. The larvae may therefore be transported away from nursery areas into unfavourable areas in which they cannot survive. Research on prawn life history dynamics, including larval distribution and abundance studies, has been conducted in the Gulf of Carpentaria, Queensland by Rothlisberg (1982, 1988), Rothlisberg *et al*. (1983a,b; 1985,1987) and Jackson *et al*. (1989). Carrick (1996) studied the spatial and temporal distribution of *M. latisulcatus* larvae over two spawning cycles in Spencer Gulf and found that larval densities were higher at the northern part of the Gulf than in the south (Figure 2.9). Residual Maximum Likelihood (REML) was used to analyse larval density transformed (square root number/100 m^3). Mean larval densities were 29.9, 6.9, 3.5 and 1.9 for transects 1, 2, 3 and 4, respectively and the standard error of the differences was 3.71. The analysis showed that there were significantly ($p<0.001$) more larvae in the two most northern transects than in the southern transects, and that latitude, water temperature and salinity were significant covariates accounting for differences in larval numbers.

The results suggest that most larval production is concentrated north of latitude 34°30'S which coincides with the location of main prawn nurseries (see below). Another penaeid (*Metapenaeopsis sp*) was also abundant in Spencer Gulf, which had fewer species of penaeid larvae than all other known penaeid fisheries.

Larval densities were significantly higher in 1993 than in 1994, which was reflected by higher recruitment to grounds in 1994 than in 1995. Research has demonstrated seasonal and inter-annual variation in larval abundance with peaks in zoea numbers in December and February, coinciding with the two gonad maturation peaks. Carrick (1996) postulated that several factors were significant in larval dispersal and post-larval settlement. These were: circulation patterns induced by tides, winds, spatio-temporal patterns in egg production, water temperature, and differential survival of larval phases.

2.2.4 Juvenile prawn nurseries and population dynamics

The post-larvae settle in shallow inshore nursery areas, where they can remain up to 10 months depending on the time of settlement. The post-larvae produced from early spawning settle in nursery areas in December/January, grow rapidly and emigrate to deeper water as sub-adults in May-June. Post-larvae produced from a late January spawning settle in nurseries from March, grow more slowly and over-winter in the nursery areas before recruiting to the grounds in February. Hence, there are two types of recruitment patterns, namely, direct recruits which have a short residence period in nurseries, and over-wintered recruits which have a longer residence period (8-10 months) in nurseries.

An investigation to determine the location of main juvenile prawn nurseries in Spencer Gulf was undertaken (Carrick 1996, Carrick and Williams 2001 & unpublished). Fifty sites from Tumby Bay to Blanch Harbour on the western side of the Gulf, and from Wardang Island to Chinaman's Creek on the eastern side of the Gulf were sampled (Figure 2.10). Mean densities of juvenile prawns were higher on the western side of the Gulf than on the eastern side, with highest densities at Blanche Harbour and in the False Bay, Shoalwater to Plank Pt regions in the west, and from Pt Broughton to Chinaman's Creek in the east. However, low prawn densities at a number of sites in False Bay near coke furnace settling ponds may be associated with high chemical contamination (e.g., iron, lead, arsenic and ammonia) of nursery sediment in the area .

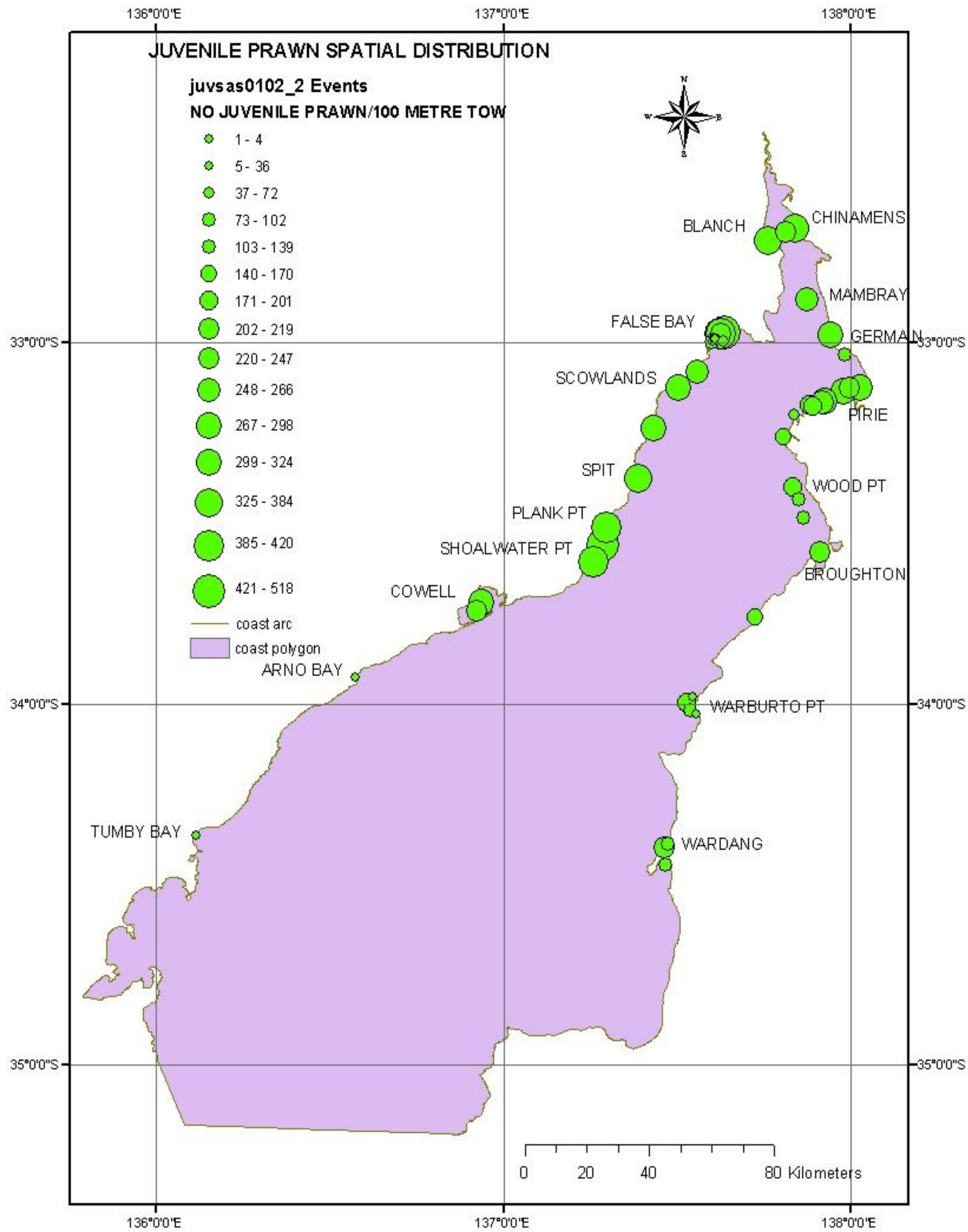


Figure 2.10: Map of main juvenile prawn nurseries and mean density (number/100 metre tow) of juvenile prawns on the eastern and western sides of Spencer Gulf.

The natural mortality (M) of juvenile prawns in inshore prawn nurseries is high but is lower than for other penaeids (Table 2.3). Weekly instantaneous mortality rates were determined in Spencer Gulf by sampling from June to November, when the population was closed (i.e. no immigration or emigration). The study was based on a period when mortality was expected to be low. The mortality estimates are for over-wintered recruits to nurseries.

Natural instantaneous mortality rates are the lowest reported in the literature. Results of M proved to be low but varied between years and were correlated with initial density, suggesting that density-dependent survival may "control" juvenile abundance. Further, strong recruitment to nurseries in April resulted in strong recruitment to the fishery; this may be associated with high densities, and low M of over-wintered recruits in nurseries (Carrick, Craig & Olsen, unpublished).

Table 2.3:Comparison of juvenile prawn mortality rates reported in the literature.

Author	Area	Species	Period	Weekly instantaneous rate	% Weekly mortality
O'Brien (1994)	Moreton Bay, Queensland	*P. esculentus*	Minimum	0.06	5.82
			Maximum	0.29	25.17
			1988-89	0.15	13.93
			1989-90	0.17	15.63
Minello *et al.* (1989)	Gulf of Mexico	*P. aztecus*	1989	na	33.60
Haywood & Staples (1993)	Gulf of Carpentaria	*P. merguiensis*	Maximum range	na	60.90
			1988	na	26.00
			1989	na	38.70
			1990	na	36.90
Carrick (1996)	Spencer Gulf	*M. latisulcatus*	1992-93	0.050	4.88
			1993	0.064	6.20
			1992	0.037	3.63

2.3 Management of the fishery

2.3.1 The Fisheries Act 1982

The prawn fisheries of South Australia are managed pursuant to the Fisheries Act 1982. This legislation is an Act "…to provide for the conservation, enhancement and management of fisheries, the regulation of fishing and the protection of certain fish; to provide for the protection of marine mammals and the aquatic habitat; to provide for the control of exotic fish and disease in fish, and the regulation of fish farming and fish processing; and for other purposes". It provides a broad statutory framework to ensure the ecologically sustainable management of South Australia's marine, estuarine and freshwater fisheries resources. In the administration of the Act, the Minister for Agriculture, Food and Fisheries, the Director of Fisheries and the Fisheries management Committees must operate in accordance with the following objectives (section 20):

(a) Ensuing, through proper conservation, preservation and fisheries management measures, that the living resources of the waters to which this Act applies are not endangered or overexploited; and
(b) Achieving the optimum utilisation and equitable distribution of those resources

South Australia has management jurisdiction for western king prawns (*M. latisulcatus*) from the low water mark out to 200 nautical miles in the waters adjacent to South Australia. Regulations governing the management of the South Australian prawn fisheries are established in the *Fisheries (Scheme of Management-Prawn Fisheries) Regulations 1991 and the Fisheries (General) Regulations 2000.*

The South Australian Government, in consultation with key stakeholder groups and the broader community, is currently undertaking a comprehensive review of the *Fisheries Act 1982.* This review, which is expected to be completed in 2005, may result in changes to the broad framework for administering and managing South Australia's fisheries resources, and may require amendments to the subordinate regulations.

2.3.2 Fishery Management Plans

Management Plans are also prepared for particular fisheries to provide a detailed framework of management policies, objectives, strategies and performance indicators to be employed for sustainable management of each fishery, and provide direction for the formulation of regulations contained within relevant schemes of management and the general regulations.

Fishery management plans do not have any statutory basis, but rather provide a formal foundation for the management of each fishery to continue moving towards a more integrated management framework. The powers contained in s.14 of the *Fisheries (Management Committees) Regulations 1995* provide the legal basis for the preparation of management plans. Responsibility for the preparation of the management plans rests with individual Fishery Management Committees.

There are two management plans for South Australia's prawn fisheries:

- *The Spencer Gulf and West Coast Prawn Fisheries Management Plan (1998)*
- *The Gulf St Vincent Prawn Fishery Management Plan (1998).*

Generally, the plans operate for a 5-year period, and are subject to annual review and amendments considered necessary by the Minister for Agriculture Food and Fisheries and the Director of Fisheries.

2.3.3 Objectives of the Management Plans

Consistent with the objectives of the Fisheries Act 1982, a key goal of the Management Plans is to ensure that an appropriate balance exists between the need to ensure the long-term sustainability of the resources and the optimum utilisation of these resources between stakeholder groups and future generations. There are a number of more specific biological, economic, environmental and social objectives that have been developed to complement the broader directives of s.20 of the Act.

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 the 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 the 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. The Plan represents the commitment of Government, industry, and the community to manage the fishery through the application of the recommendations of the National Strategy for Ecological Sustainable Development developed by the Council of Australian Governments in December 1992. Regulations pertaining to the management of prawn fisheries in South Australia are documented in outlined in the *Fisheries (Scheme of Management-Prawn Fisheries) Regulations 1991.*

2.3.4 Reference points and performance indicators

Reference points are agreed quantitative measures used to assess the performance of the fishery based on defined management objectives. Caddy and McMahon (1995) and others have provided a detailed background on the conceptual and applied aspects of reference points for fisheries management. Reference points enable the development of a decision framework, however, reference points and performance indicators have to be updated and refined regularly. There are two types of reference points for the rational exploitation of fisheries namely:

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

Morgan (1996) recommended a number of biological reference points for the Spencer Gulf prawn fishery, which have been adopted by PIRSA Fisheries. The biological reference points consist of the following 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. The limit reference point for protecting the resource is that exploitation should not reduce the stock to a level below 40 percent.

- Maintain the recruitment index at a level which ensures suitable recruitment to the fishery. The reference point is based on the 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/h 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 kilogram. The Management Plan states that the size of prawns taken during fishing operations should be monitored nightly to ensure that effort is targeted to prawns that 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 (MacDonald 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" (Table 2.4). However, there is also potential to induce recruitment overfishing by premature intensive harvesting of aggregations of large potential spawners.

Table 2.4: Fishery performance indicators and biological reference points for the Spencer Gulf Fishery.

Indicator	**Target reference point**	**Limit reference point**
Effort (days)	70-80 days*	80 days*
Spawning biomass (% virgin biomass)	50 %	40 %
Recruitment Index	40	35
Size at capture	<40 per kg	40 or more per kg

*Effort is effective effort days and not nominal days

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/h 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 <33 and females <35 mm CL) per nautical mile (nm) trawled from trawl surveys over the main recruitment area of the Gulf.

3 Need

It has long been recognized by research and majority members of the fishing industry that fishery sustainability can only be maintained if fishing effort is constrained and directed in space and time with an adaptive and real-time management approach. Such limitations on harvest strategies (e.g., closures and controls of trawl effort) are often difficult to define and the interests of individuals in the fishing industry may influence management decisions with potential impact on the fishery. Discussions on how to limit the spatial and temporal extent of fishery closures and the amount of trawl effort will always occur within the fishing industry. This is where objective decision support is needed most (Walters and Ludwig 1979, Hilborn and Walters 1992). We show how the DSS is used to increase fishery sustainability, (Carrick and Ostendorf 2004 in press). Management decisions need to be made rapidly within 5 to 12 hours of completing trawl surveys. The compilation and analysis of data is required for communication to a FMC sub-committee responsible for developing harvest strategies. Hence, there is a need for an effective database system, analytical tools for analyses and model simulation, knowledge of fishing operations, as well as an electronic (ADSL) system for the communication and implementation of harvest strategies.

The Spencer Gulf prawn fishery is managed in real time. The adaptive mode and role and functions of Government and industry are outlined below (Figure 3.1). The stock size, size of prawns captured and levels of stock depletion are monitored on a daily basis using CDMA, facsimile and email thereby allowing a direct exchange of information from vessel to shore and vice-versa. Owing to the dynamic nature of the stock (e.g., movement of sub-optimal size prawns into fishing areas, high depletion of spawners) the fleet needs to respond to real-time changes in harvest strategies, which are broadcast to the fleet by a radio base situated in the main port at Wallaroo. The fleet works at night, information being exchanged overnight or early morning.

The real-time management system occurs in collaboration between Government (PIRSA) and industry to ensure fishing operations are sustainable and economically efficient. The system uses trawl survey data, information from a CAS (CAS) and modelling, to determine the optimum utilisation of the resource. The CAS has an important role which involves discussing and communicating information to the fleet and coordinating operations with a shore base maintained by a fishery scientist. The fishery scientist develops harvest strategies in collaboration with the CAS; the information obtained in real time can be evaluated and subsequently discussed at FMC meetings (see Appendix 4 for some photographs).

The real-time management system utilises background information on fishery biology, data sources, database systems and modelling. Real-time data from surveys and commercial operations is integrated to determine the best harvest strategy to ensure stock sustainability and the economic performance of fishing operations. Information sources and methods include:

- Fishery-independent stock assessment surveys
- Adaptive “spot”, fishery-independent surveys
- Real-time information from the fleet on daily prawn size and spatial catch
- Catch and effort and size composition data, from SARDI system and fishers’ historical data
- Oracle integrated systems: survey, spawning, prawn movement, prawn size, catch and closures.
- Modelling-spawners, recruits, SRR, depletion and exploitation, fishing power estimation, harvest optimisation for value and maximisation of egg production.

- Spatial systems and GIS mapping
- Decision frameworks, risk and feedback control

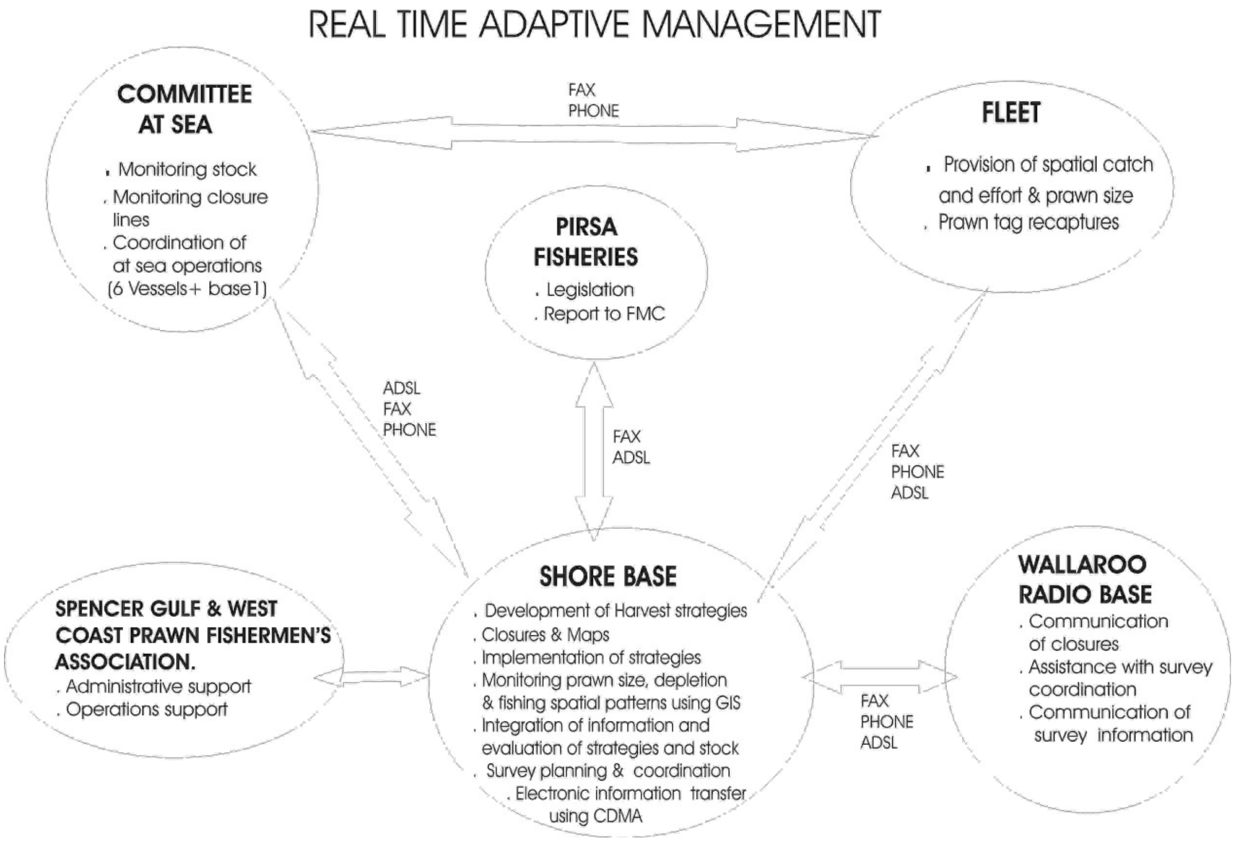


Figure 3.1: Real-time adaptive management functions.

The daily monitoring system includes networking with operators via CDMA phone, fax and email by ADSL broadband. The following is undertaken daily:

- Modelling and evaluation of daily depletion rate and prawn size composition.
- Evaluation of reproductive maturation (and spawning status) and reproductive depletion over main spawning period.
- Assessment of the potential for closure line problems
- Developing and enhancing harvest strategies and closures including buffer lines
- Mapping closures and sending text for implementation of changes to PIRSA Fisheries, Wallaroo Radio Base and CAS.

The data collected from the Spencer Gulf and West Coast prawn fisheries is large and complex and consisted mainly of fishery-independent trawl survey, prawn tag mark-recapture and commercial catch and effort data. In the past, it has not been possible to provide detailed analyses of such data due to the lack of an integrated database system with facility to group and integrate diverse data sets. A major objective of the study was to develop an integrated database system with the capacity to run procedures from the desk top, test for errors and missing data and for direct link to software for a rapid analysis and visualisation of results. There was a need to document the historical changes that have taken place in the fisheries and the benefits resulting from the refinement of harvest strategies. Understanding of spatial processes in the distribution of abundance, prawn movement and growth, fleet behaviour and the effect of fishing and environment on prawn populations was considered most important for the development of harvest strategies in the fisheries.

4 Methods

The database was developed using the software Oracle 8i with SQL Plus scripts. The database is documented in detail from an information technology perspective in three separate documents (Appendix 5). The specific data analysis and modelling methods regarding the application of the database for research and management are described within the respective chapters. An outline overview of the structure of the analysis chapters is detailed below (Figure 4.1).

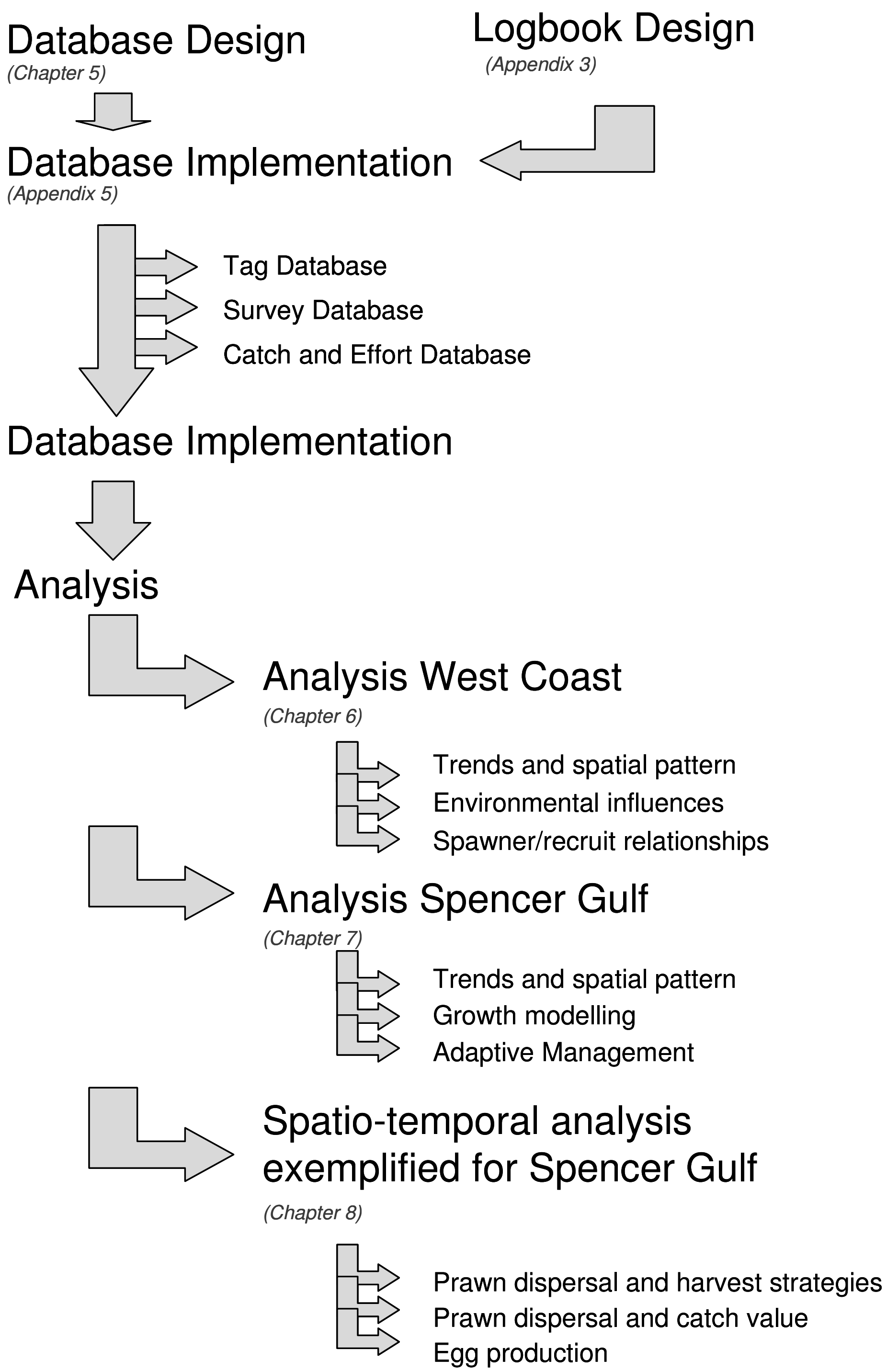


Figure 4.4.1: Overview of method chapters.

5 Database development

5.1 Database design considerations

5.1.1 Introduction

The fishery-independent 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. "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.

Fishery-dependent commercial catch and effort data (CMS)

Catch Monitoring Systems (sometimes known as Catch Effort systems) record commercial prawn trawling results. This data is then used to support analysis of prawn stock and harvest levels. The CMS maintains data about the spatial location and times of commercial prawn trawling catches, price history and vessel attributes all of which can be used in stock assessment and management. The system maintains auxiliary data components consisting of commercial size (grade, no/lb), sample size frequency and average size data using bucket counts (no.prawns/7.2 kg). The historical catch and effort data is comprised of fishing period landings (or monthly landings), daily logbook data with data files consisting of fishing grid, block, date, time shot away, trawl duration (min), depth, and catch (kg) and water temperature (℃). The fishing period landings consists of frozen product (cartons) and brine. Additional modules comprising processor grades and archived closures files provide historical information on the size of prawns captured and different types of harvesting strategies adapted. A new logbook system was designed and implemented in collaboration with industry in 2001 where point data (GPS positions) of trawl shots over fishing night are recorded. Initially it was planned to test electronic transfer of data from vessel to shore via CDMA. However, insufficient support from industry hindered the progress made in automated data capture and electronic transfer.

Tag database (TDB)

A comprehensive mark-recapture database was set up to enable prawn tag release and recapture files to be assembled for determination of prawn movement and growth patterns. Prawn types mainly used consisted of Hallprint tags and colour coded tags. The data entry system incorporated 'built-in" checks for validation and error correction.

Fisheries independent surveys and PRS

Fishery-independent trawl surveys are required to estimate recruits and spawners, egg production, spatial size composition and trawl value over grounds. The surveys are required as a large area of the gulf is closed to trawling and there is a need to obtain data on the abundance of prawns in open and closed areas for stock assessment. Fishery logbook data cannot provide reliable estimates of recruits to grounds owing to spatial restrictions imposed on the fleet and rigid operational policy in real time management (RTM) to eliminate and reduce the capture of small prawns. Background research has shown that major recruitment occurs in the northern area of the Gulf where time series data has been used to derive reference points. Recruits to grounds are classified according to different size (mm carapace length or mm CL) categories for male and female prawns. Three major surveys take place through a year for assessment of stock, recruits and spawners and for estimation of depletion or the amount of prawns removed.

The main stock assessment surveys provide vital information on stock with information used to develop harvest strategies. Information on biomass density, levels of recruits and the abundance of spawners is 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) is 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 is obtained from surveys, simulations are carried out to determine the optimum period to fish different areas. The fisheries independent survey system referred to as prawn research system (PRS) is a most comprehensive spatial database which is integrated to the other database systems developed. PRS consists of data entry screens, tables of attributes and deck-top procedures for amalgamation and analysis of data and includes NT6, NT7 and NT8 (see below). Field tests on electronic transfer of survey data using CDMA were conducted and proved successful.

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 CAS assists 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-o protect small prawns and juvenile fish (King George Whiting and Snapper).
- Seasonal area closures- variable and used to protect small prawns, prevent reproductive depletion, and optimise the 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 protect spawners.
- Total Gulf moon closures– to reduce fishing inefficiency and maintain the quality of catch.
- Daylight closures– to reduce fishing inefficiency and further reduce impact of trawling on discards and habitat.
- Depth limit- Trawling is prohibited in all waters less than 10 metres in depth to protect seagrass and associated biological assemblages.

Appendix 6 provides detail of the location of the generalised types of trawl fishing closures. The database system needs to facilitate the determination of spatial and temporal closures with historical closures archived in CMS.

5.1.2 Decision making and design of the database

The objectives were to develop an integrated system for research and management decision support. The core is a database that assembles and organises historic data and information obtained in real time.

The key objectives of the system are to:

- Allow rapid information processing

- Develop a link of spatial and non-spatial data with statistical analysis software, visualisation and communication tools
- Allow the fast analysis of fishery data and assess spatial and temporal patterns in catch size composition and depletion for modelling
- Improve fishery monitoring and stock assessment using efficient information communication, GIS mapping and analytical techniques
- Allow comparison with historical harvesting strategies

One key aspect of the system is to allow the rapid evaluation of real-time survey data through spatial visualisation and a statistical comparison with historical data. With visual analysis and statistical evaluation, management decisions are more objective because they are based on a vast amount of knowledge and information from historic harvesting, survey and catch effort data and simulation. A further objective was to develop an efficient data collection system. Technological means exist for streamlining the reporting process but implementation may be limited by legal as well as logistic constraints.

The decision support system (DSS) will only be used by a very limited number of people in a few committees (CAS and the FMC). Therefore, less effort is required for user friendliness. The two key design strategies were:

- Efficiency
- Comprehensiveness.

Efficiency was maximised by using the most advanced database technology (ORACLE), a commercial GIS (ArcGIS) and statistical software packages (SPLUS, GENSTAT, Figure 5.1). Comprehensiveness was ensured by incorporating government and industry databases and placing effort on entering historical data, applying a rigid quality control at the level of data entry into the database and visualising spatial pattern.

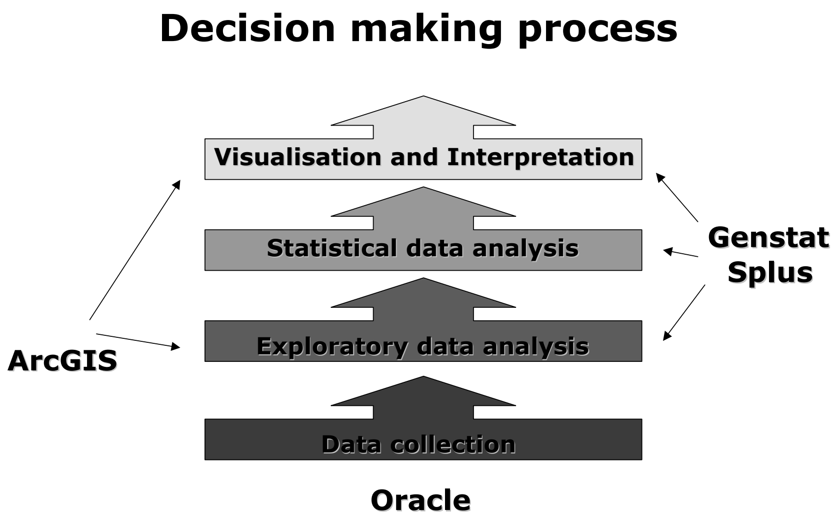


Figure 5.1: The steps in the decision making process and the linkage of commercial software packages in the support system.

Technically, the linkages between the software components of the DSS were kept as simple as possible. The core is the Oracle database through which all data flows are controlled. The exchange between different software components 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 therefore 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 tools from a rapidly changing developing software market.

The database application is made up of separate but linked modules, titled PRS (Prawn Reporting System), TAG (Prawn Tagging Releases and Recaptures) and CMS (Catch Effort Monitoring System). The integrated database system was developed for the Spencer Gulf and the West Coast prawn fisheries.

PRS holds survey log records and associated prawn sample records. As it was the first application to be developed, it holds some data, such as survey definitions, survey stations, vessel and prawn grade data which is also used by the other applications. Some data was migrated from an old Dataflex database and some reports are based on original FOCUS reports. More recent data has been entered by hand through the Oracle forms (screens) designed for data entry, review and correction.

TAG holds data on the release of tagged prawns and any subsequent recapture of a tagged prawn. Prawns are tagged and released in consecutive batches at recorded locations and once recaptured, have their tag, location sex and size recorded. This enables the measurement of growth and estimation of movement of prawns over time.

CMS (Catch Monitoring System), sometimes known as Catch and Effort, records commercial prawn trawling results. This data is then used to support the analysis of prawn stock and harvest levels.

The documents in Appendix 5 are intended as an application user document in a broad sense, in that they each contain a range of information that any user of the applications might require to support data entry, reporting and analysis.

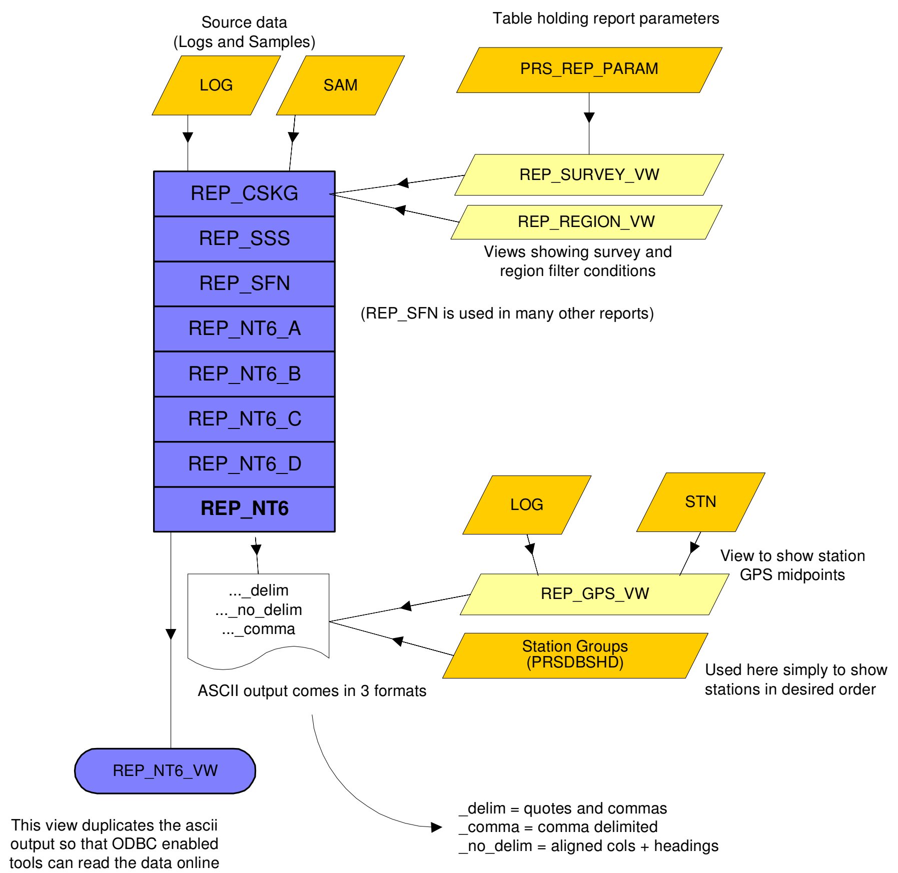
The applications are written using Oracle software for the database, screens and reports. Other software such as ESRI's products, GENSTAT, SPLUS and Microsoft Excel is used to conduct statistical analysis, spatial representation and data migration assistance. Data from the Oracle database is accessed by these products online via ODBC and OLE DB.

Contents of the documents include:

- Basic operator instructions for Oracle products, including some common techniques for users to get the best out of these.
- Menu structure and details of application screens to assist the user's understanding of the application interface.
- Notes on reports including an explanation of the different report output formats and data flows to derive these reports.
- An explanation of some key spatial concepts as they apply to the applications.
- Detailed data structures including indexes. This is included to support subsequent database development and future detailed analysis.

The information in Appendix 5 is intended to provide a picture of the methods and database applications. This includes all data structures, data entry processes and reporting and data access choices. The main database procedure used in "crunching" and structuring data is NT6 (Figure 5.2).

REPORTING ANATOMY
REP_NT6



REP_NT6_OUT_with_Station_Model

(As above but includes Wholeblock etc from a specific Station Model)

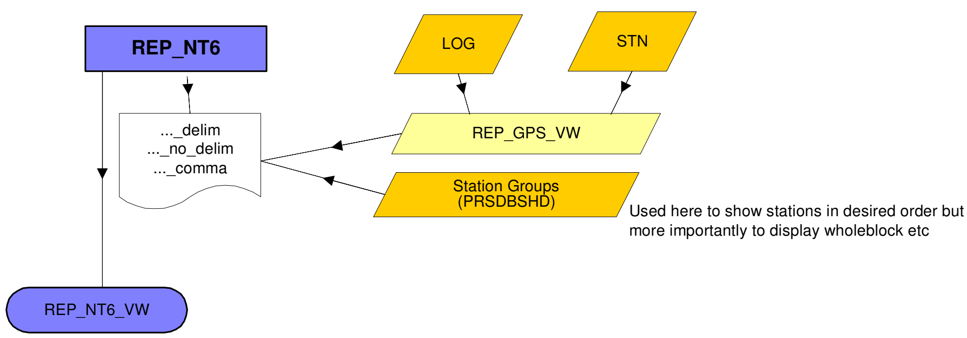


Figure 5.2: Outline of prawn Oracle database procedure NT6 run from the desktop (see appendix 5).

NT6 takes the log file (catch kg, minutes, trawl distance) and size frequency file data and uses a raising factor to estimate prawn numbers over size from 15-65 mm CL and reproductive potential. Data from NT6 are 'passed' to other procedures to estimate a large suite of population parameters including the size and grade composition of catch, recruits, and spawners. NT6 is integrated to location data from each trawl (latitude/longitude) with ODBC connection to statistical modelling and GIS software for statistical analysis and visualisation of results.

Research undertaken for the FRDC project on the West Coast prawn fishery include:

- Development of a survey database system in Oracle.
- Development of an environmental database including modules for sea level and sea surface temperature (SST), sea level height (SLH), wind and rainfall.
- Development of a Oracle catch and effort monitoring system with ODBC link to GIS software.
- Development of an Oracle tag database and determination of prawn movement vectors in the Venus Bay region.
- Analysis and visualisation of spatial patterns in prawn catch and effort
- Analysis and visualisation of fishery-independent trawl surveys for the assessment of spatial and temporal distribution patterns in recruits and spawners.
- Study of sea level and surface water temperature patterns and ENSO events
- Modelling the spawner- recruit relationship (SRR) and the influence of environmental variation on recruitment
- Visualisation and animation of prawn movement vectors

There are fundamental differences in the structure of the fishery-independent survey (PRS) database systems for the Spencer Gulf and West Coast prawn fisheries. The differences in structure reflect the spatial sampling plans and the grouping of sampling units (stations) for ANOVA, REML and process modelling applications (see below).

The integrated spatial database for the West Coast has similar architecture to the Spencer Gulf system. SQL procedures (NT6, FAM, NT7 & NT8, see below) have been tested and are being enhanced to incorporate a variety of spatial models required for statistical analysis. The systems developed for the Spencer Gulf and the West Coast prawn fisheries by Rowan Hosking (Oracle database programmer) are state-of-the-art in the development of a fishery spatial database and reporting system. The system is most powerful and with additional programming can be "tailor-made" for numerous applications in fishery, agricultural and ecological research. The system allows different types of data files to be generated and used in the study of the distribution and dispersal of prawns, for stock assessment and bio-economic modelling. As in Spencer Gulf, the database system was developed to generate files which can be used to determine a spawner-recruit relationship (SRR) and the influence of the environment on recruitment and stock. Testing of the tag database system was undertaken using a field experiment in June 1990 and it is noted that the collapse (and closure) of the fishery in 1993 prevented recaptures of tagged prawns.

Data from satellite sea surface temperature imagery, obtained from NASA AVHRR Pathfinder 4 satellite imagery archives, sea level height, sea water temperature, air temperature, wind and rainfall (from the National Tidal Facility, Bureau of Meteorology) and other data sources are being imported into Oracle as an environmental database for the West Coast and Spencer Gulf prawn fisheries. Other data from 'ad-hoc' sources is being compiled and it is planned to import them into the Oracle system in the future. The project will facilitate the development of a Decision Support System (DSS) for management decision making in the West Coast prawn fishery where an effective database system and statistical tools are required for rapid statistical analysis, harvest model simulation and objective interpretation of results.

6 West Coast Analysis

6.1 Trends and spatial patterns in prawn catch and nominal effort

6.1.1 Background

A square grid system is mainly used for the West Coast commercial logbook daily catch and effort system, (Figure 6.1). However, the dimensions of the grids at Venus Bay are rectangular in shape owing to the need to obtain finer spatial data on catch and effort in the Venus Bay region where alignment of grids followed most frequent trawl direction which takes place parallel to shore in the region, (see Anon 2003).

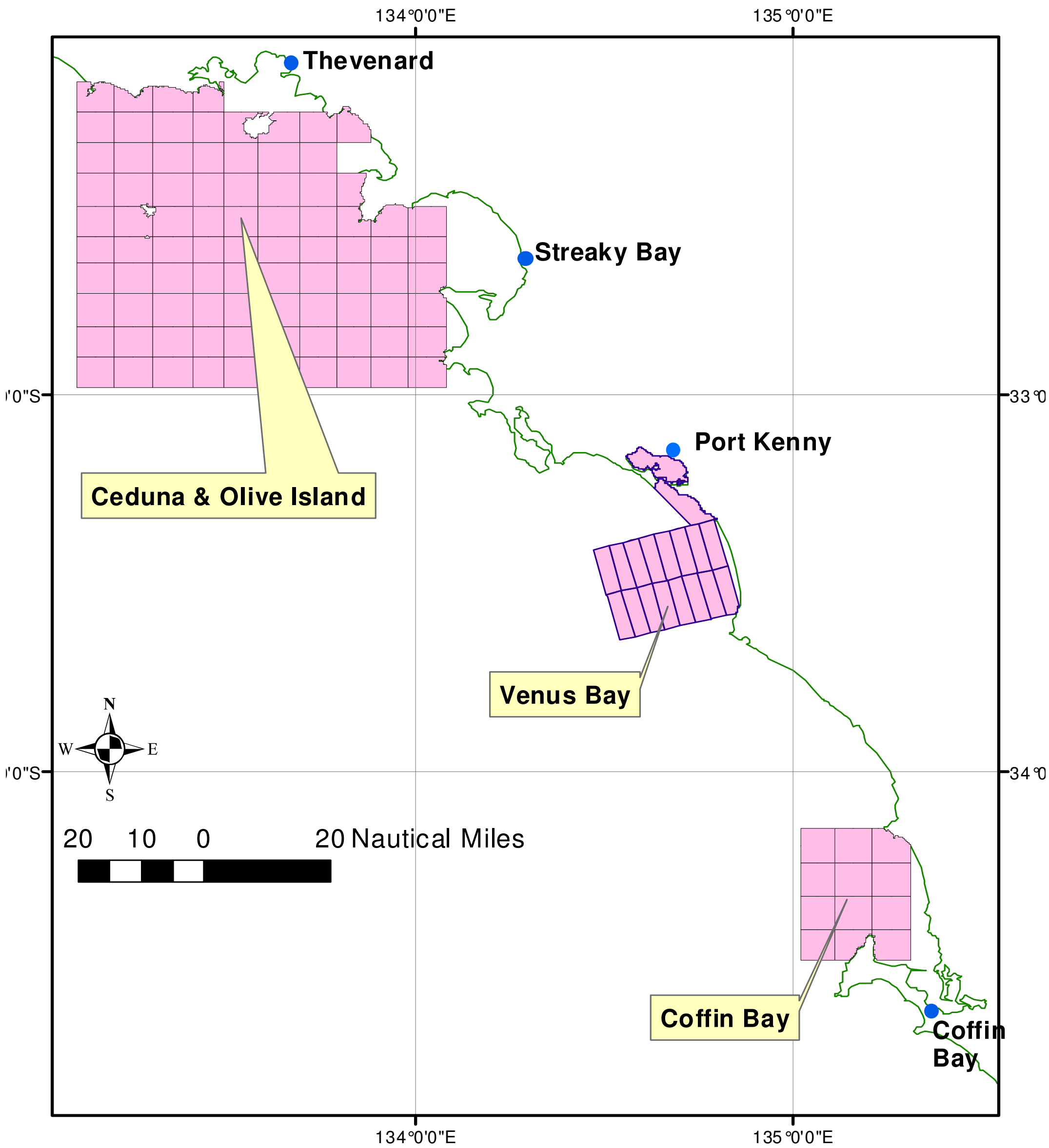


Figure 6.1: Location of West Coast prawn commercial fishing blocks used for stock assessment.

As in Spencer Gulf, the fishery is based exclusively on the western king prawn, *M. latisulcatus*. Only 3 operators are licensed to trawl for prawns in the area. Annual trends in fishery production and nominal effort (hours trawled) from 1978-79 to 2001-02 are illustrated in. The fishery collapsed in 1992-93 and was closed to trawling except for limited research monitoring at the main ground at Venus Bay.

Historical trends in production and nominal effort from 1978-79 to 2001-202 for the West Coast prawn fishery show that a major stock decline occurred in 1992-93 (see Anonymous 2003), (Figure 6.2). The fishery was closed to trawling in 1993 with the objective to re-habilitate the stock through reduction in exploitation. The recovery of the West Coast prawn fishery was relatively fast compared to fish stocks which have 'collapsed' (see., Hilborn and Walters 1992).

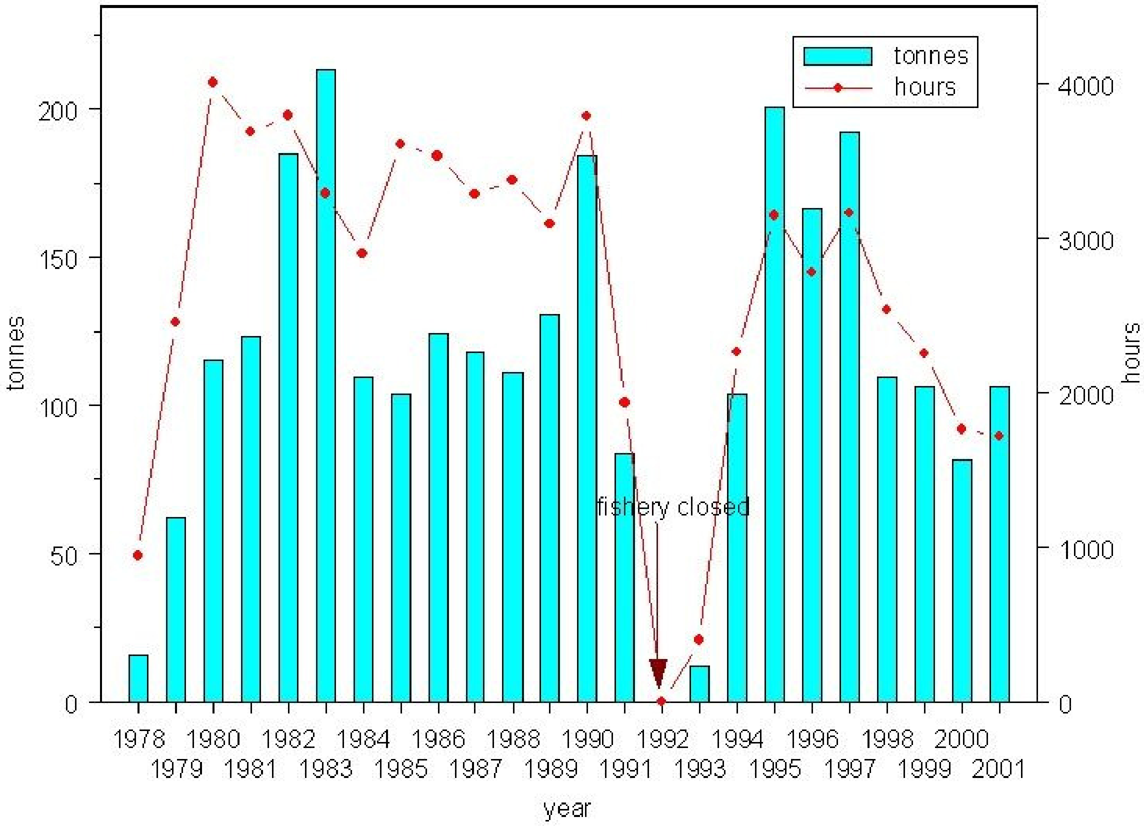


Figure 6.2: West Coast prawn production (tonnes) and nominal effort (hours) in the 1978-1978 to 2001-2002 financial years.

Wallner (1985) provides a detailed account of the West Coast prawn fishery and research undertaken from 1983 to 1985. Carrick (1993) hypothesised that the decline in the fishery in 1993 was likely to be due to a number of factors including El Nino Southern Oscillation (ENSO) events affecting currents and larval supply to prawn nurseries, cold sea water temperatures over critical larval dispersal periods, overfishing of key spawner areas and possibly large scale movement dispersal of prawns from the area. In the case of the latter, a 'catastrophic' reduction in the spawning stock would generate a subsequent decline in stock if recruitment at Venus Bay was derived from the spawning population in that area. As in Spencer Gulf, fishery production is driven by recruitment; hence, understanding the processes (environmental and exploitation) which affect recruitment is of paramount importance to management.

Survey sampling took place consistently from 1990-1997, mainly in the Venus Bay region as cost, logistic and weather problems prevented more regular sampling at Ceduna. The Venus Bay ground has consistently contributed to >65% of the West Coast prawn catch and fishery-independent trawl data from the region is assumed to be reflective of variations in recruitment and stock size.

6.1.2 Fishery production results

Polygon shape files were produced by digitising charts for the fishery based on blocks. The Venus Bay area has fishing blocks aligned in rectangles (8 X 2 nautical miles) and running alongshore to capture detailed spatial patterns in catch and effort with spatial closures used to protect small prawns within the inshore blocks. For all other regions, including the Ceduna and Coffin Bay areas, fishing blocks consist of square blocks (5 x 5 nautical miles).

The spatial distribution of landings from 1990-91 to 1996-97 financial years was compared to show the collapse and recovery in the fishery as no other penaeid fishery has experienced such a ‘catastrophic’ collapse with negligible recruitment occurring in 1992-93 when the fishery was closed to fishing. Such a collapse may be due to the fact that the West Coast fishery is at the lower range of the species distribution. It is an oceanic penaeid trawl fishery, more likely to be influenced by large scale oceanographic events than Spencer Gulf which is expected to be less influenced by large scale oceanographic perturbations and more environmentally predictable. Although the fishery is small, the research undertaken is of value to penaeid fishery science as the literature does not contain any example of such a dramatic decline and recovery in a fishery monitored by fishery-independent trawl survey and CPUE derived from commercial catch and effort data.

Landings in 1990-91 were 184.2 tonnes for 3 789 hours, the main catch being landed from the Venus Bay area. In 1993-94 the annual catch was 11.9 tonnes with most of the catch taken from the Ceduna grounds (blocks 307 and 308 (Figure 6.3 and Figure 6.4). In 1994-95 the fishery recovered from the decline with 103.5 tonnes landed, with further increase in production to 203.8 tonnes in 1996-97 (Figure 6.5 and Figure 6.6). Historically, Venus Bay produced >60 % of the annual fishery catch and the collapse of the fishery was most evident in the Venus Bay region.

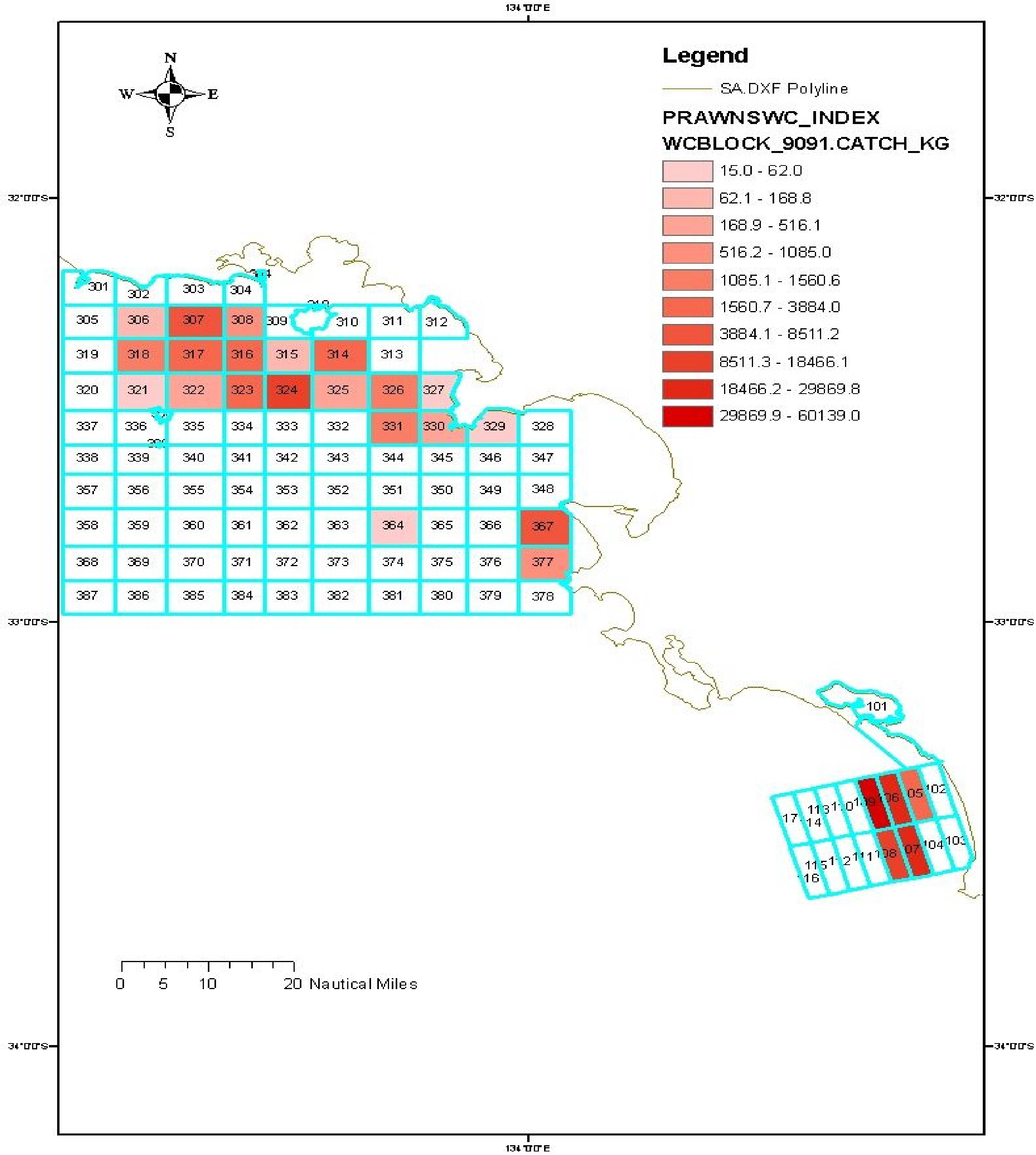


Figure 6.3: Prawn landings (kg) by fishing block in the West Coast prawn fishery, 1990-1991.

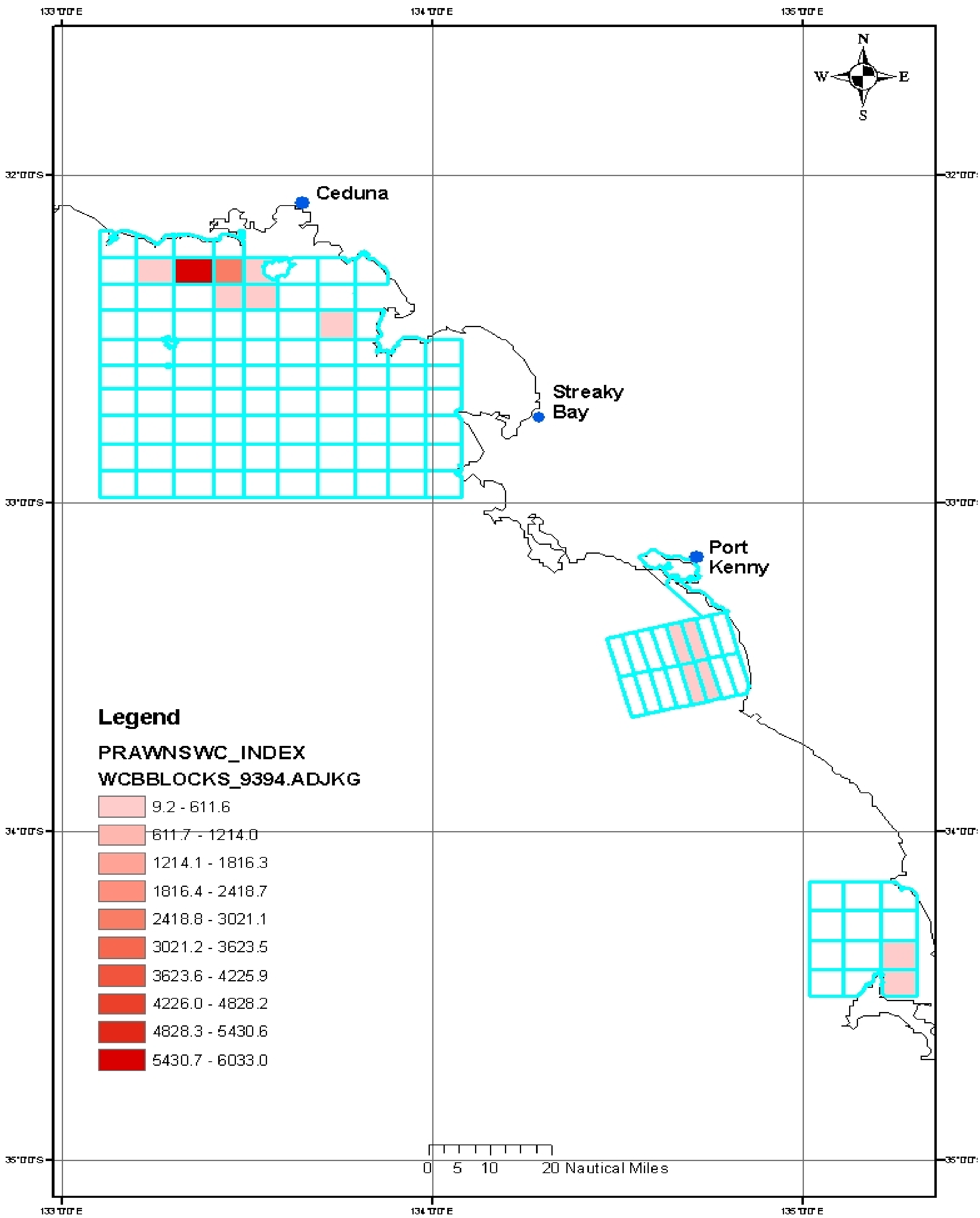


Figure 6.4: Prawn landings (kg) by fishing block in the West Coast prawn fishery, 1993-1994.

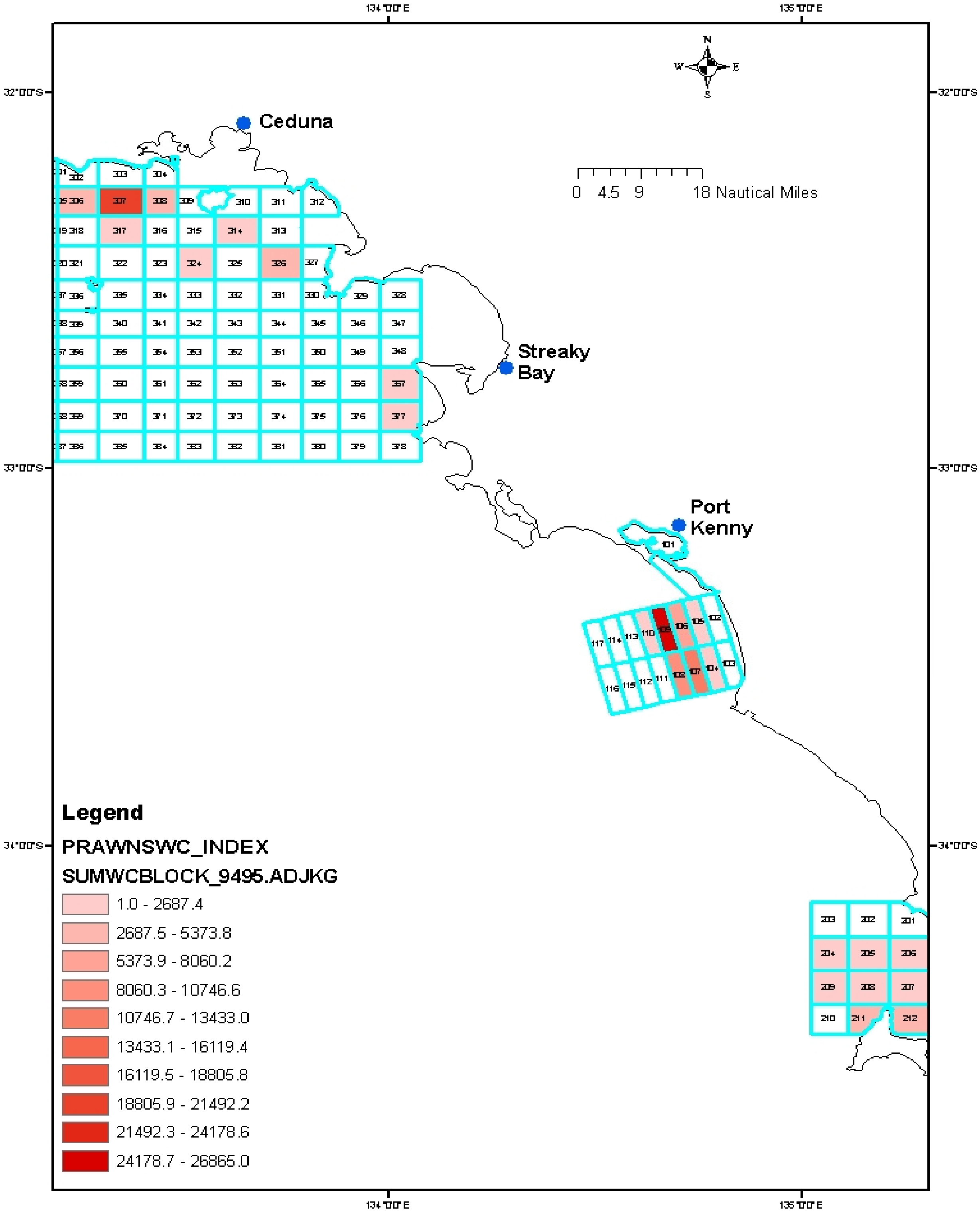


Figure 6.5: Prawn landings (kg) by fishing block in the West Coast prawn fishery, 1994-1995.

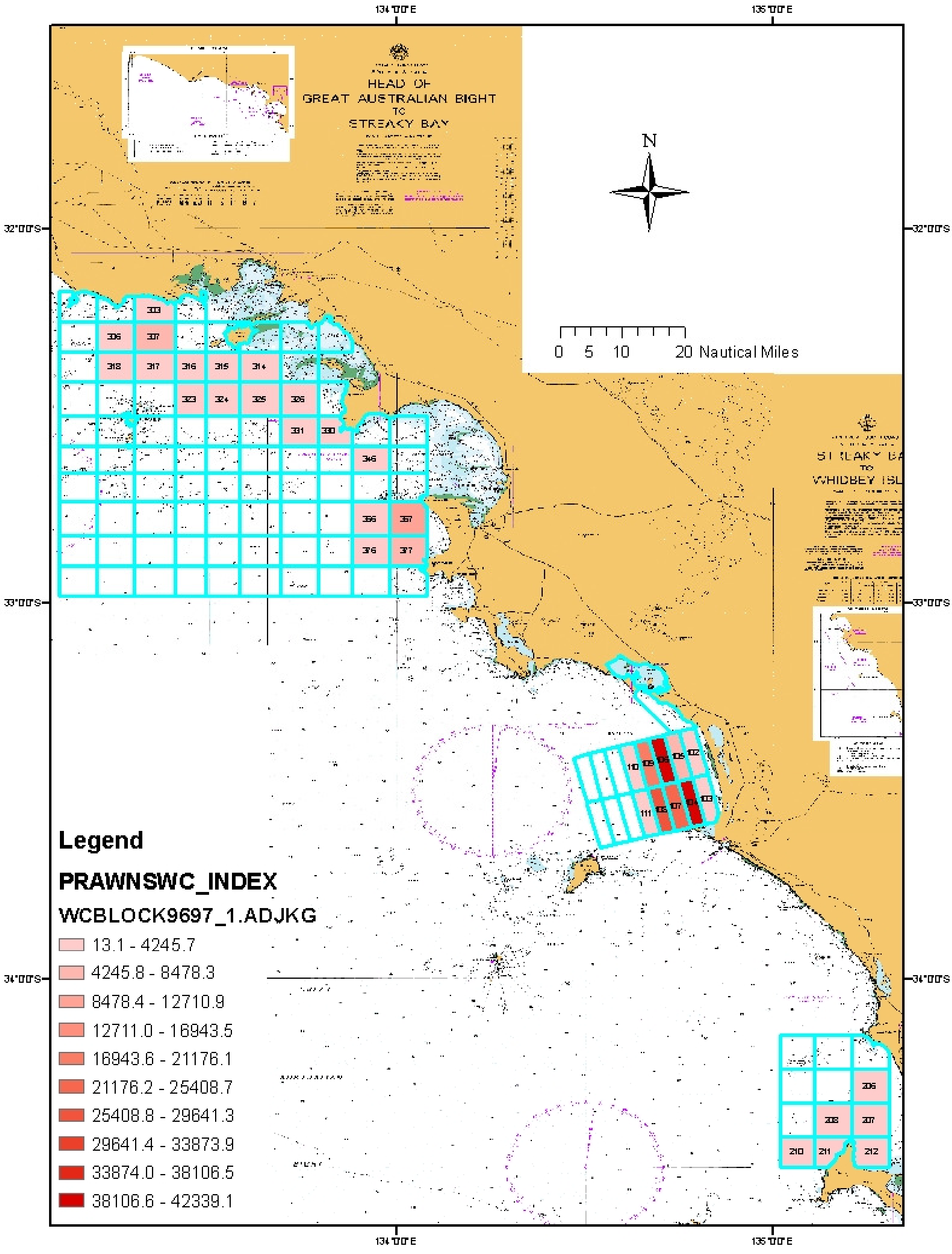


Figure 6.6: Prawn landings (kg) by fishing block in the West Coast prawn fishery, 1996-1997.

6.2 Spatial and temporal distribution of recruits, spawners and eggs over the Venus Bay grounds.

6.2.1 Methods

Fishery-independent trawl surveys were mainly conducted at Venus Bay (also referred to as Anxious Bay) from 1990-1997 with the sampling plan consisting of trawling sites over 3 different levels of shore or zones (inshore, mid-shore and offshore; (Figure 6.7).

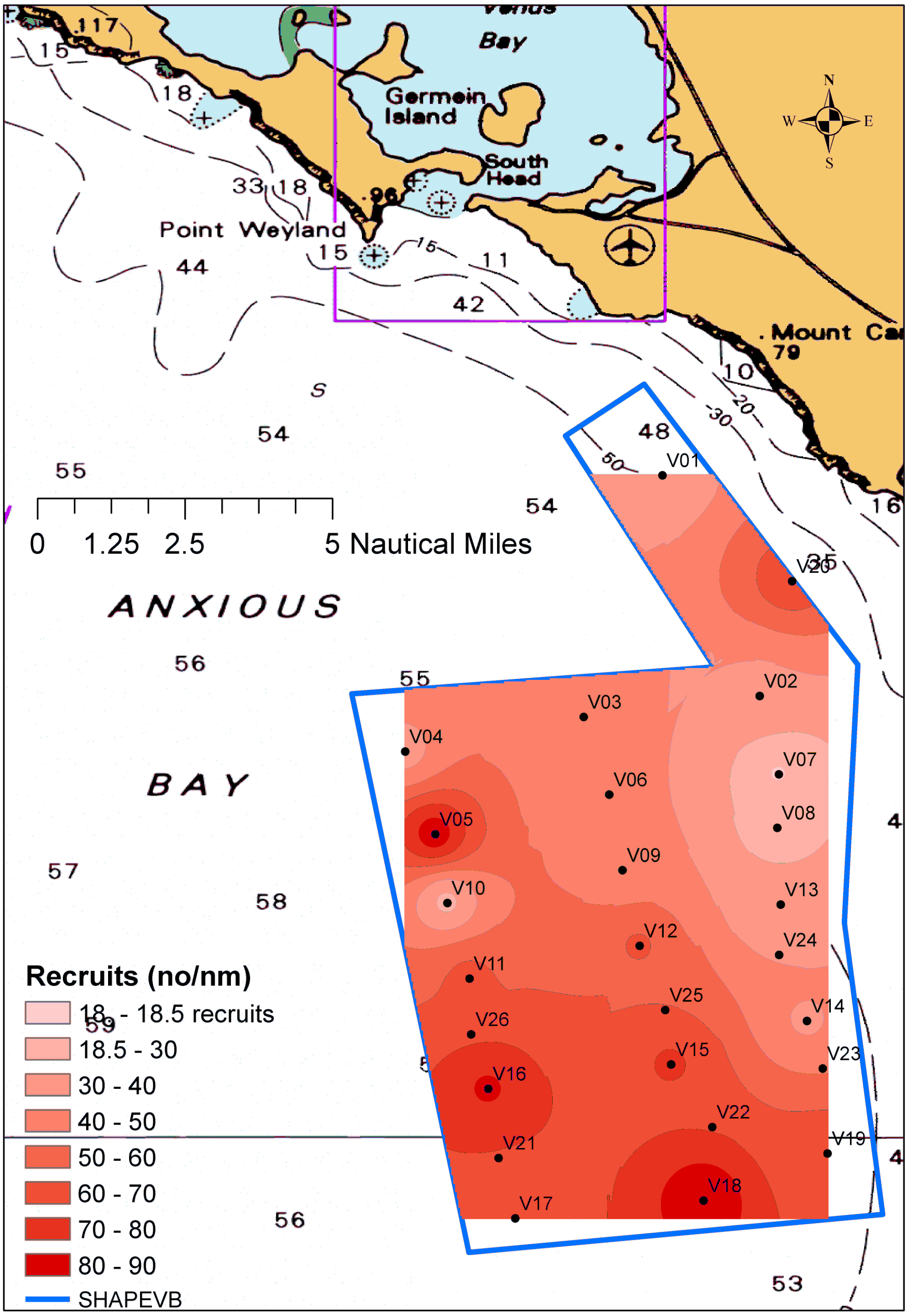


Figure 6.7: Location of fishery-independent trawl sampling sites (v01-v26) with inverse difference interpolation of prawn recruit density (no/n mile) in June 1992 using a boundary polyline.

The main objective of the study was to determine spatial and temporal trends in recruitment and to examine the influence of spawning stock and environmental variation on recruitment. The sampling plan at Venus Bay was originally based on a balanced structure for ANOVA and is the main sampling plan reported. The sampling plan was designed to compare differences in response variates (recruits, spawners, egg production) over 3 Zones (inshore, mid shore and offshore), 3 Lines (along shore) with 2 plots within each line. The sampling plan sampled across shore (across environmental depth gradient), as background research (unpublished) indicated that sampling across an environmental gradient is more precise than sampling along an environmental gradient. The fishery-independent sampling plan was as follows:

(a) Block Plot, Treat Year*Zone*Line for annual June surveys from 1991-1997.
(b) Block Plot, Treat Year* (Zone/Line) for annual June surveys from 1991-1997.

Trawl distance was mainly limited to 1.7 nautical miles (approx. 30 minutes). In 1996 the number of sampling sites was increased from 18 to 26 to obtain more detailed spatial information and to increase sampling precision. Routine sampling was discontinued in 1997 owing to logistic and funding constraints. The Oracle system and reports (SQL Plus) were used to generate output files for statistical analysis and GIS mapping. Spatial data (longitude, latitude and response variates) for each sampling site was subjected to simple visualisation techniques using ArcMap with a boundary (polyline) used for spatial interpolation of data. Trawl sampling survey data on recruits from June surveys from 1991 to 1995 was mapped to visualize recruit spatial distribution before the collapse of the fishery and until its recovery. Visualisation of recruit abundance (no/n mile trawled) was undertaken by using 10 abundance scales with equal intervals within each of the four years.

6.2.2 Results

An examination of residuals from ANOVA indicated that the square root transformation of all response variates (recruits, eggs and large spawners) stabilized variance patterns. Two recruit sizes were used in analyses viz. 32-34 and 34-39 mm CL for male and female prawns, respectively. The selection of recruit sizes was based on the identification of cohorts from plots of sample size frequency data and mixture fitting (Fournier *et al*. 1990). The Oracle reporting system provided a tool for generating recruit densities (no/n mile) at each site for each size group for pooled sexes.

The analysis of variance of square root recruits for the 32-34 and 34-39 mm CL groups showed significant main effects of Year, Zone and Line with significant interactions in Year.Zone and Year.Line. The interaction Zone.Line was not significant ($p = 0.13$) and was nested in Zone. Appendices 7a-c detail the analyses of variance of square root number of recruits, pooled by sexes (males >33 and females <35 mm CL). The Year effect shows a large decline in recruits from 1991 to 1993 which was followed by a substantial increase in densities which reached maximum level in 1997 (Figure 6.8).

The Year x Zone interaction is of interest; only in 1991, 1994 and 1997 is there a defined spatial gradient in abundance which decreases across Shore. Background work using February survey data from 1990 to 1992 showed that recruit numbers were significantly ($p<0.005$) higher inshore, suggesting seasonal variation in recruit spatial distribution with recruits dispersing from the inshore area along shore to the southern section of the ground, .

A comparison of 1991 and 1995 recruit mean density and standard deviations indicated that 88 sampling sites were required to obtain a power of 0.8 (alpha = 0.05) and the sampling plan reported (6 sites x 3 zones) had a power of 0.31 (alpha = 0.05). An increase in the number of sampling sites to 24 would result in a power of 0.40, with a delta level of 2.07. Clearly, the effect size is most important as only 6 sites were required to detect a significant difference between recruitment abundance in 1991 and 1993 at power of 0.8. The results obtained from using the larger recruit size (males <35 and males <40 mm CL) show a similar trend of decreasing density from 1991 to 1993 and an increasing trend from 1993 to 1997. There was no significant difference in recruit densities between 1994 and 1997 indicating that the fishery recovered from the 1993 recruitment collapse in June 1994 following a year of closure of the fishery to trawling.

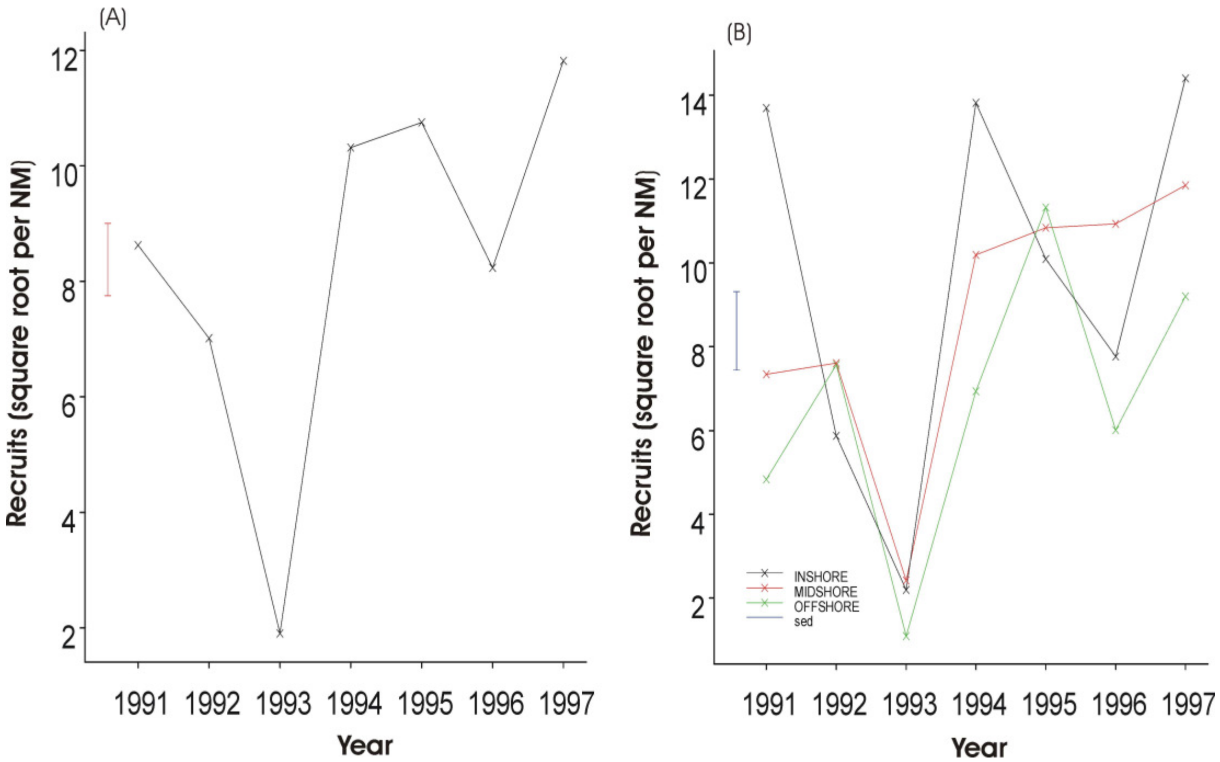


Figure 6.8: Analysis of variance of mean recruit (32-34 mm CL) density (square root no/n mile) over Year (1991-1997) and Zone - (A) Year effect and (B) Year x Zone interaction effect.

The spatial distribution of recruit density (no/nm) before, during and after the collapse of the fishery was mapped to include data from 2 sites closest to the estuary entrance (Figure 6.9). Except for 1991, recruits have highest density in the inshore zone in the northern sector of the region zone with an abundance of recruits in 1993 relatively low over all sites (maximum abundance scale 37-40 recruits/nm) compared with other years with zero counts at sites closest to the southern boundary of the area. The distribution of recruits at the recovery phase in 1994 and 1995 had the highest density in the inshore zone of the northern sector of the zone with abundances >380 and 500 recruits/nm for 1994 and 1995, respectively (Figure 6.9 C & D).

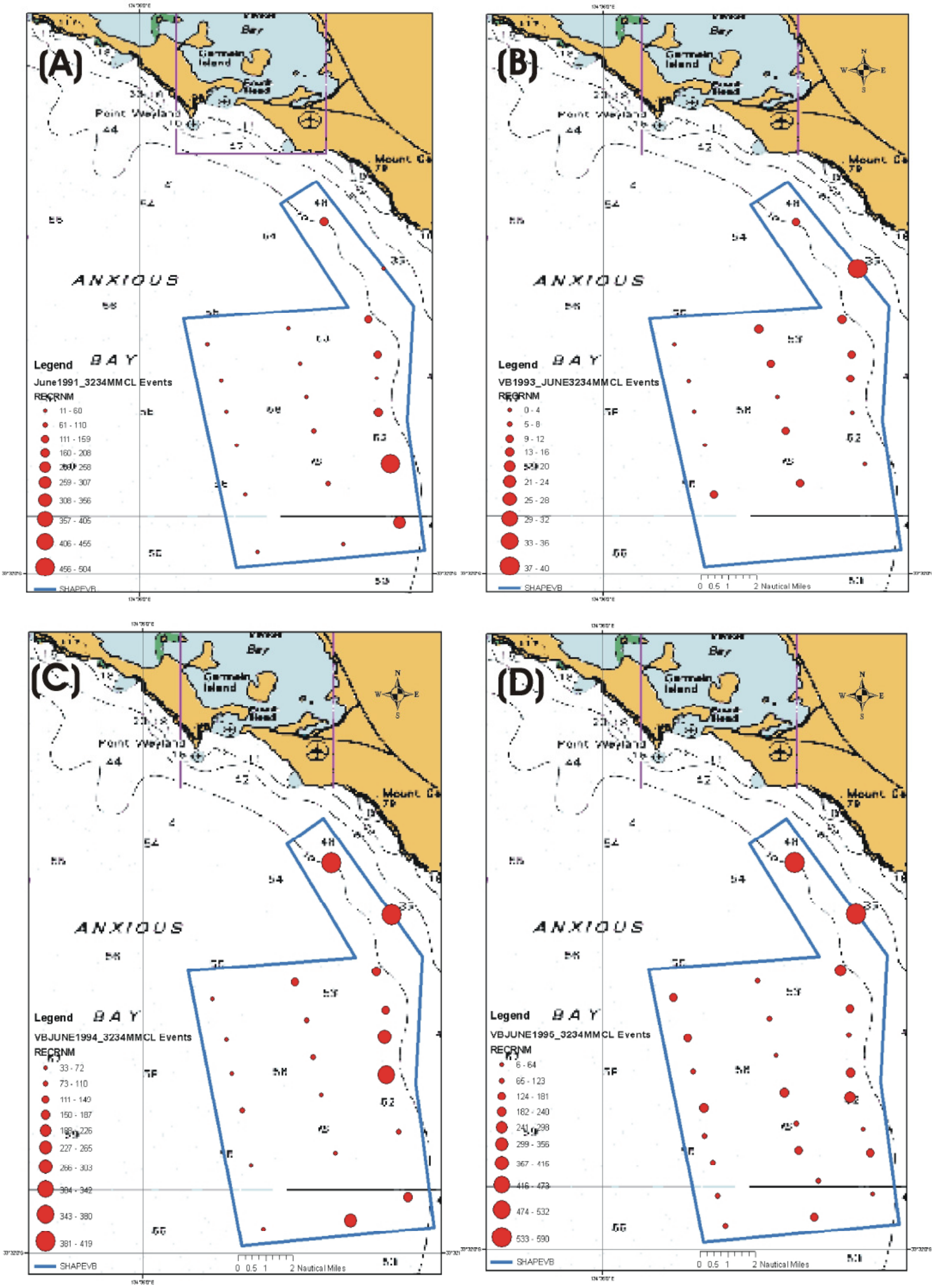


Figure 6.9: Spatial patterns in recruit density (no/n mile) at Venus Bay over June sampling periods. A-1991; B-1993; C-1994 & D-1995.

Results show that prawn recruitment increased significantly in June 1994 and the fishery recovered from the population 'crash' which occurred in 1993.

Spawners and egg production at Venus Bay

The number of effective spawners (female prawns >42 mm CL) showed a significant decline in mean density from 1991 to 1993 and an increasing trend to 1996 (Figure 6.10). Results of ANOVA main and interaction effects are detailed in Appendix 7d. The magnitude of the decline in large spawners from 1991 to 1992 was larger than the decline in recruitment. The decline in spawners in 1992 is likely to be attributable to movement dispersal from the area and/or exploitation.

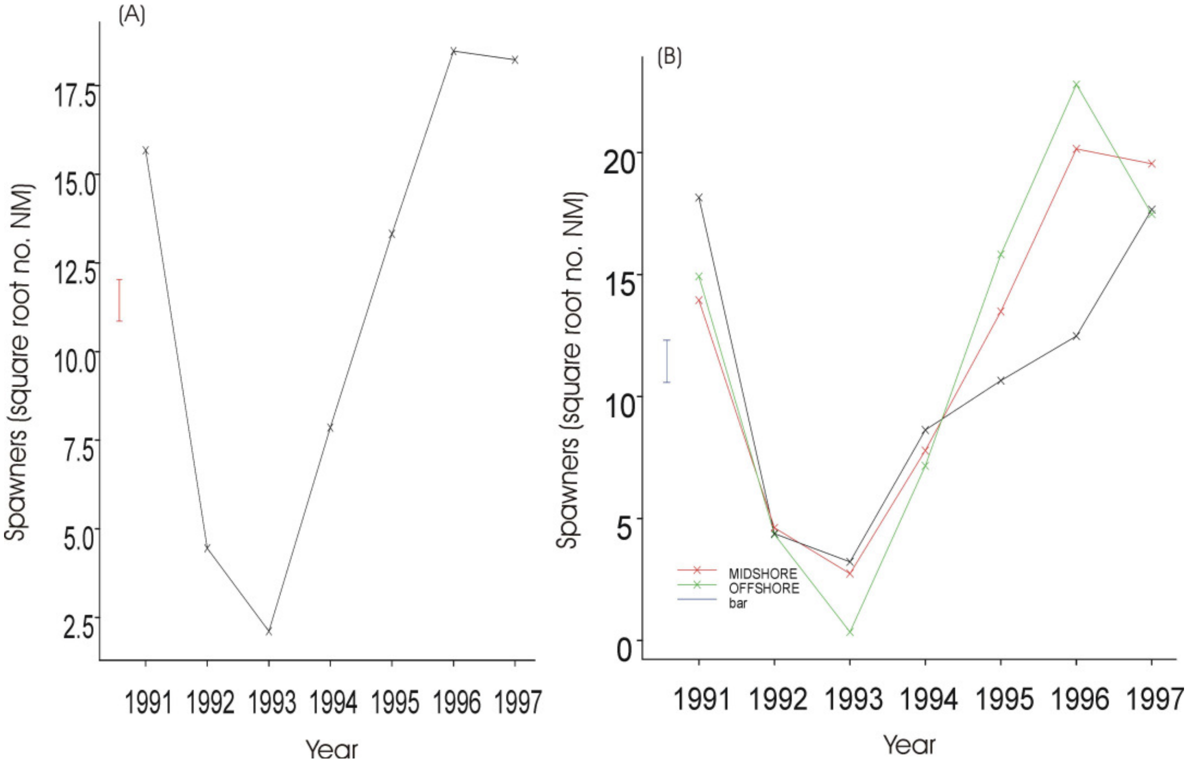


Figure 6.10: Analysis of variance of mean effective spawner density (square root no/nm) over Year (1991-1997) and Zone at Venus Bay- (A) Year effect and (B) Year x Zone interaction effect.

Egg production, a function of prawn density and female fecundity, has a similar trend to density of spawning prawns except it does not display a strong linear trend from 1993 to1996 compared to spawners (Figure 6.11). The correlation between egg production and density of large female prawns was 0.991 indicating that the density of female prawns (>42 mm CL) is a good indicator of spawners with ANOVA results detailed in Appendix 7e. The rate of increase in egg production over time mirrors the trends in densities of effective spawners, except for a lower rate of increase for egg production from 1993 to 1996.

Results show that a large recruitment of small prawns occurred in June 1994 when the number of large prawns was relatively low, resulting in a subsequent increase in egg production as prawns increased in size with growth.

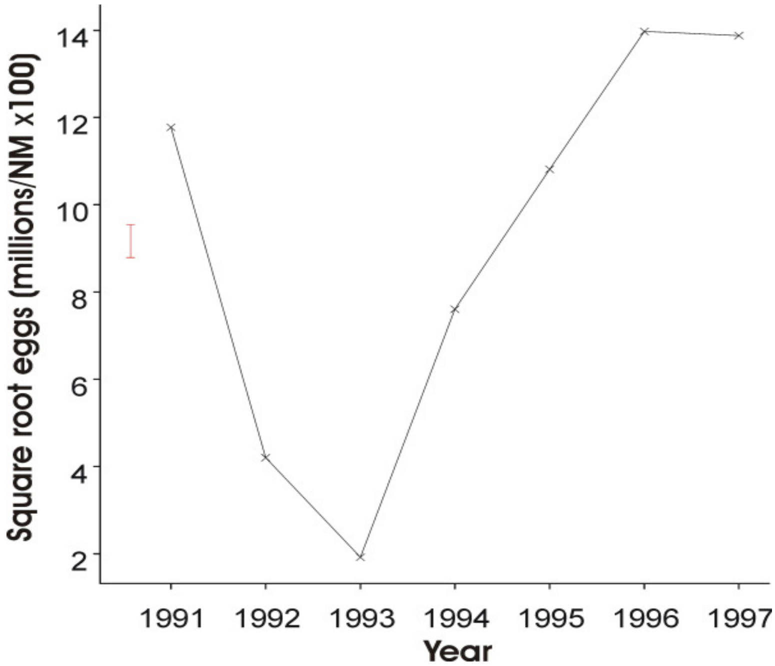


Figure 6.11: Analysis of variance of mean egg production density (square root no/n mile) over Year (1991-1997) at Venus Bay.

The research supports the hypothesis (Carrick 1993) that the supply of recruits at Venus Bay is derived from the adjacent estuary, as a clear spatial gradient in recruit density is evident with highest densities occurring closest to the estuary entrance. In productive years, there are larger abundances of recruits in the inshore zone which is evident in 1994 when the fishery recovered from recruitment decline. The narrow entrance of the main nursery (<0.4 n mile in width; Figure 6.9) may be a natural restriction to the supply of prawn larvae to nurseries, especially when advection by currents is unfavourable. It is hypothesised that the spatial distribution of spawners may be most important for fishery sustainability at Venus Bay. It would be advantageous for successful breeding to release eggs closest to the entrance. Background analysis has shown that the spatial distribution of egg production in February is higher in the inshore region, with egg production greatest closer to the estuary entrance (unpublished). However, the spatial distribution in egg production in 1992, although low, was atypical in that the inshore region had the lowest mean density.

In 1993 the fishery was closed to trawling for 18 months followed by spatial closures to protect spawners at strategic periods. The main objective of management was to allow maximum spawning to take place to increase the rate of recruitment for stock recovery. The results demonstrate that the fishery made a relatively fast recovery from catastrophic stock decline with management constraints (spatial and temporal closures) on exploitation. The research demonstrates that penaeids are more resilient to stock collapse than species with a long lifespan, late maturity and low fecundity (see Hilborn and Walters 1992, Quinn and Deriso 1999). Penn *et al.* (1985) provide evidence of recruitment overfishing in Western Australian prawn fisheries with steps taken by management to ensure stock recovery which proved successful. In the most extensively researched fishery in Australia, the Northern Prawn Fishery (NFP), it has only recently been accepted by researchers that recruitment fishing has occurred (Wang and Die 1996). Despite an extensive buyback of fishing units in the NFP in the late 1980s and early 1990s, recruitment and spawner levels have not recovered from recruitment overfishing. Die *et al*. (2001). Dichmont *et al*. (2001) found that spawning stock levels for brown tiger and grooved tiger prawns in 1999 were about 33% and 44% of the estimated virgin spawning stock.

6.3 Influence of environmental variation on recruitment

6.3.1 Background

A number of key papers have addressed the influence of environmental variability in pandalid and penaeid shrimp fisheries. Hannah (1999) found that the recruitment of the pandalid shrimp, *Pandalus jordani*, in waters off Oregon, USA was negatively associated with April sea level height (SLH) and positively correlated with egg production a year earlier. Hannah suggested that alongshore transportation of eggs and larvae, as well as, near shore water temperature regimes could strongly influence shrimp survival, as supported by research by Rothlisberg (1975), Rothlisberg and Miller (1983) and Hannah (1999). Hannah found that a linear regression of sea level on log recruitment explained 48% of variation the data, and when an extreme outlier was removed a multiple regression of SLH and spawning index explained 78% of variation in recruitment. Hannah points out that the best harvest strategy for the pandalid fishery is to minimise recruitment variation by capping fishing effort on spawners in April to maintain a 'spawner threshold' as this would produce higher than average recruitment with little reduction in short-term yield.

Work by Pearce and Phillips (1988) found that El Nino Southern Oscillation (ENSO) events had a strong influence on the settlement and recruitment of the western rock lobster puerulus in Western Australia. Caputi *et al.* (1996, 1998) provided evidence of the influence of the Leeuwin current and SLH on rock lobster, prawn, scallop and pilchard recruitment to fisheries. Caputi *et al*. (1998) inferred that sea level height was an index of the strength of the southward moving Leeuwin current based on work by Pearce and Phillips (1988) who showed that fluctuations in SLH were highly correlated (r=0.82) with the Southern Oscillation Index (SOI-an index of Southern Oscillation/El Nino (ENSO) events) in Western Australia. Caputi *et al.* (1996) reported that the current was weaker during ENSO events and there was a correlation (r = 0.76) between SLH and sea surface temperature. For the western rock lobster, little or no settlement occurs in some regions unless the Leeuwin current strength is above average.

For pilchards, Caputi *et al*. (1995) found a significant negative relationship (r= -0.87) between the strength of 2-year recruits entering the fishery and the strength of the Leeuwin current (using SLH as and index of current strength) measured 2 years previously during the main spawning period. The authors suggested that larval advective processes were influenced by the Leeuwin current. For scallops (*Amusium balloti*) in Shark Bay, Western Australia, the strength of the Leeuwin current has a negative influence on larval settlement and recruitment to the fishery (Joll and Caputi 1998).

The main current in southern Australia is the Flinders current which flows in a westward direction along the shelf due to a positive wind stress curl and northward Sverdrup transport (Middleton and Cirano 2002; Middleton and Platov 2003). The oceanic West Coast prawn fishery is expected to be more influenced by the Flinders current and large scale oceanographic processes than Spencer Gulf which is a large, shallow inverse estuary with little exchange with shelf waters (Nunes-Vaz *et al*. 1990). Middleton and Cirano point out that the Flinders current is quite distinct from other major current systems of the region. The Leeuwin current is a seasonal shelf break current that enters from the west; whereas the near-coastal currents are driven by surface Ekman transport and change direction with season. Church *et al*. (1989) point out that the Leeuwin current is largely absent during summer and has little impact on circulation within the Great Australian Bight. Middleton and Cirano found that although the Leeuwin current is absent during summer a weak eastward flowing current is still found near the coast.

There has been relatively little research on the circulation and hydrography of the Great Australian Bight, the southern ocean along the Eyre Peninsula to Robe and Gulf waters.

More extensive research of the oceanographic processes and circulation patterns in southern Australia would lead to a better understanding of environmental factors which influence biological productivity including fisheries production in South Australia. Results show that prawn fishery production is recruitment driven and an understanding of the factors influencing recruitment required for the effective management of fisheries.

6.3.2 Methods

Sea water surface temperature (SST) and sea level height (SLH) were hypothesised to influence recruitment at Venus Bay and in Spencer Gulf (Carrick 1993, 1996). However, there is insufficient continuous sea water temperature data available over wide spatial scale from data loggers to enable a reliable modelling of the relationship between sea water temperature variation and recruitment. Data obtained from NHT Seaframe water temperatures at Thevenard and NASA AVHRR satellite imagery of sea surface temperature (SST) were used to determine seasonal and annual patterns in SST in the West Coast fishery.

Mean surface sea water temperature data for Thevenard from 1993-1996 and 2000 was fitted to a simple spline to examine seasonal SST patterns for the inshore West Coast region. It is noted that water temperature data from Thevenard is expected to be different from Venus Bay which is more subject to oceanic currents and cold-warm water intrusions (personal observation). The relationship between mean SLH and recruitment in June, from 1991-1999 was examined using a lag (-1 year) in February for SLH. From background work on reproductive maturation, it was assumed that in February, prawn larvae in the oceanic waters of Venus Bay would be at peak level and most susceptible to advective processes which would affect the supply of post larvae to nurseries. It was hypothesized (Carrick 1993) that variations in SLH could influence the supply of post-larvae to nurseries with impact on recruitment to nurseries and the fishery. The objective of the study was to determine the relationship between SLH and subsequent recruitment strength of prawns to the Venus Bay trawl grounds. NASA AVHRR SST data for the Venus Bay region was mapped using ESRI ArcMap and subjected to bootstrap simulation to estimate mean February SST from 1990-2003. The relationship between SLH and SST was determined with the aim of showing that oceanographic processes have a strong influence on an oceanic penaeid prawn fishery.

6.3.3 Results

Seasonal patterns in surface sea water temperatures and sea level at Thevenard.

Results have shown that there is a strong seasonal cycle in sea water temperature with maximum sea water temperature (e.g.,23.2℃) occurring in February and minimum temperature (12.1℃) in July (Figure 6.12). Sea water temperatures at Thevenard are the coldest documented for a penaeid prawn fishery.

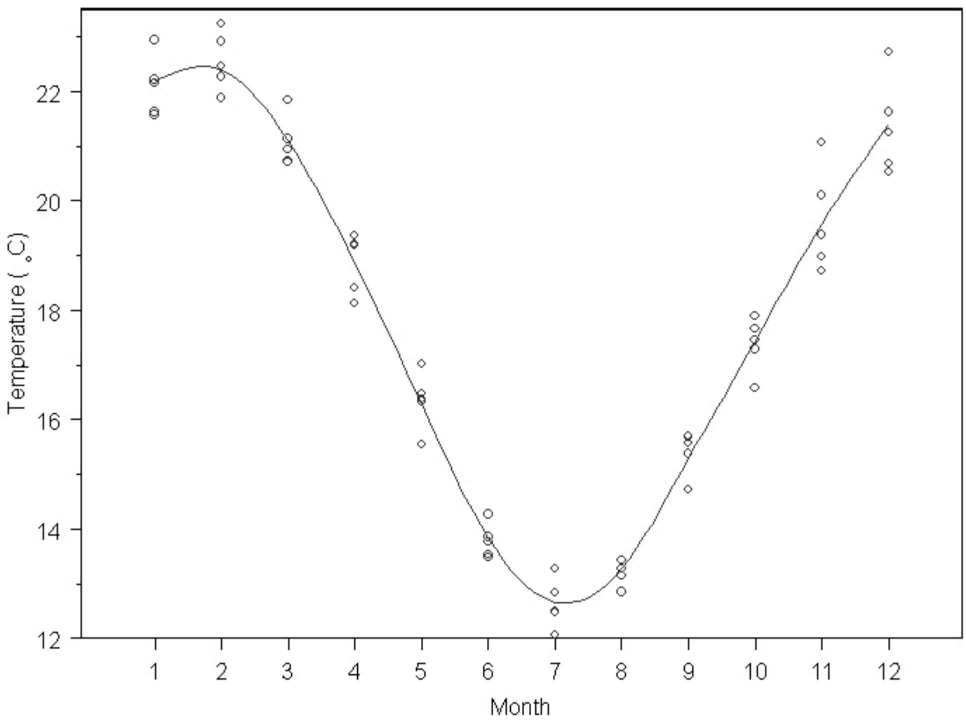


Figure 6.12: Seasonal cycle in mean sea water surface temperature (° C) at Thevenard, West Coast, South Australia. Data provided by The National Tidal Facility, Adelaide.

Results show that there was large variation in annual sea level patterns from 1990-1999, especially over January to March (Figure 6.13). A comparison of January and February sea level cycles from 1990-1999 indicates that there was larger variation SLH in January than in February (Figure 6.14). The lowest February sea level occurred in 1992 followed by 1998 with maximum sea levels for February occurring in 1997 and 1998. January sea levels were lowest in 1992 and highest in 1994.

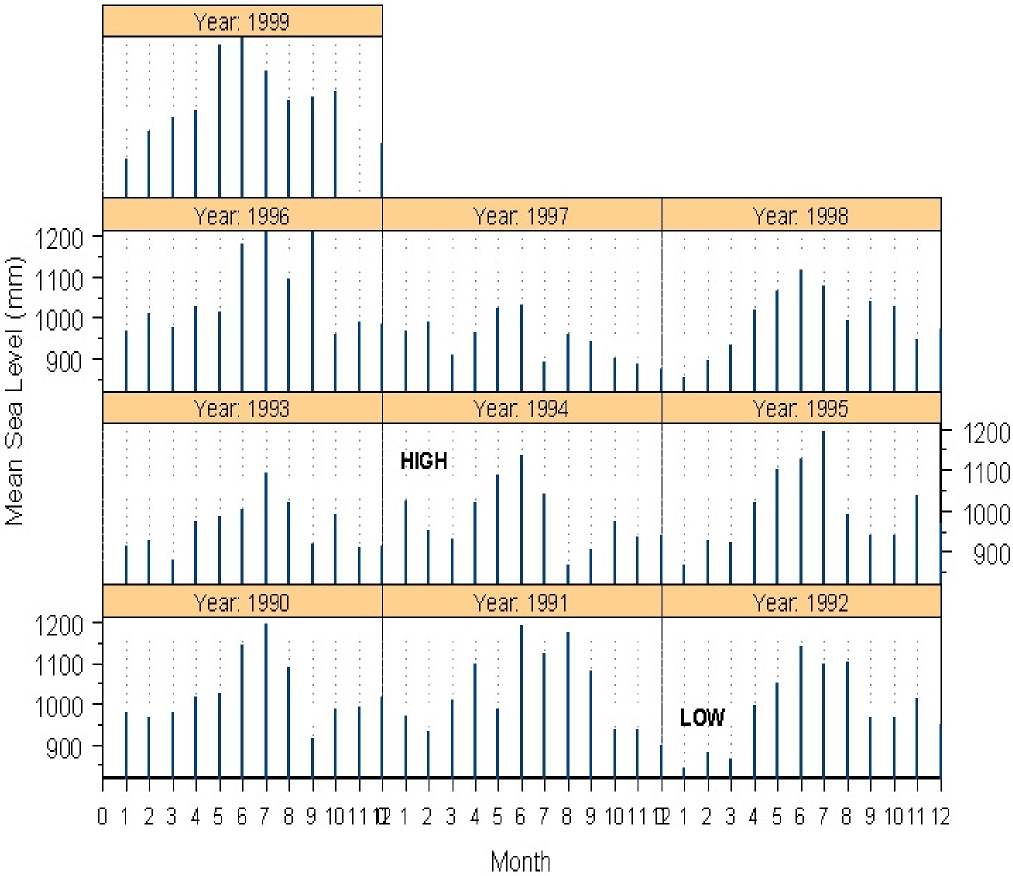


Figure 6.13: Mean sea level height (mm) trends at Thevenard, South Australia, 1990-1999.

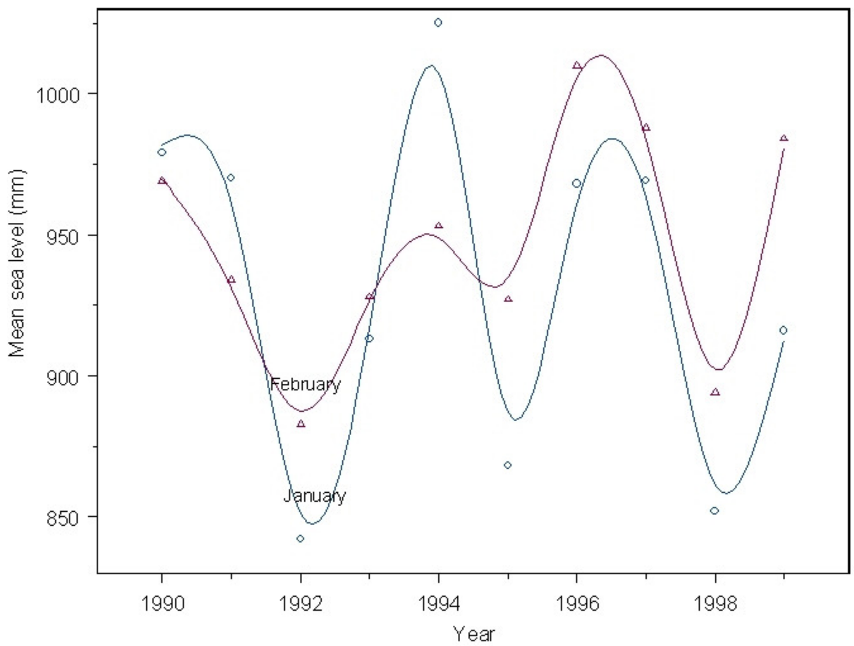


Figure 6.14: Comparisons of January and February mean sea level height (mm) from 1990-1999 at Thevenard, South Australia.

SST satellite imagery from NASA AVHRR archives (1990-2003) was downloaded using a rectangular grid covering the Venus Bay region and mapped to show spatial and temporal variations in SST patterns (Figure 6.15).

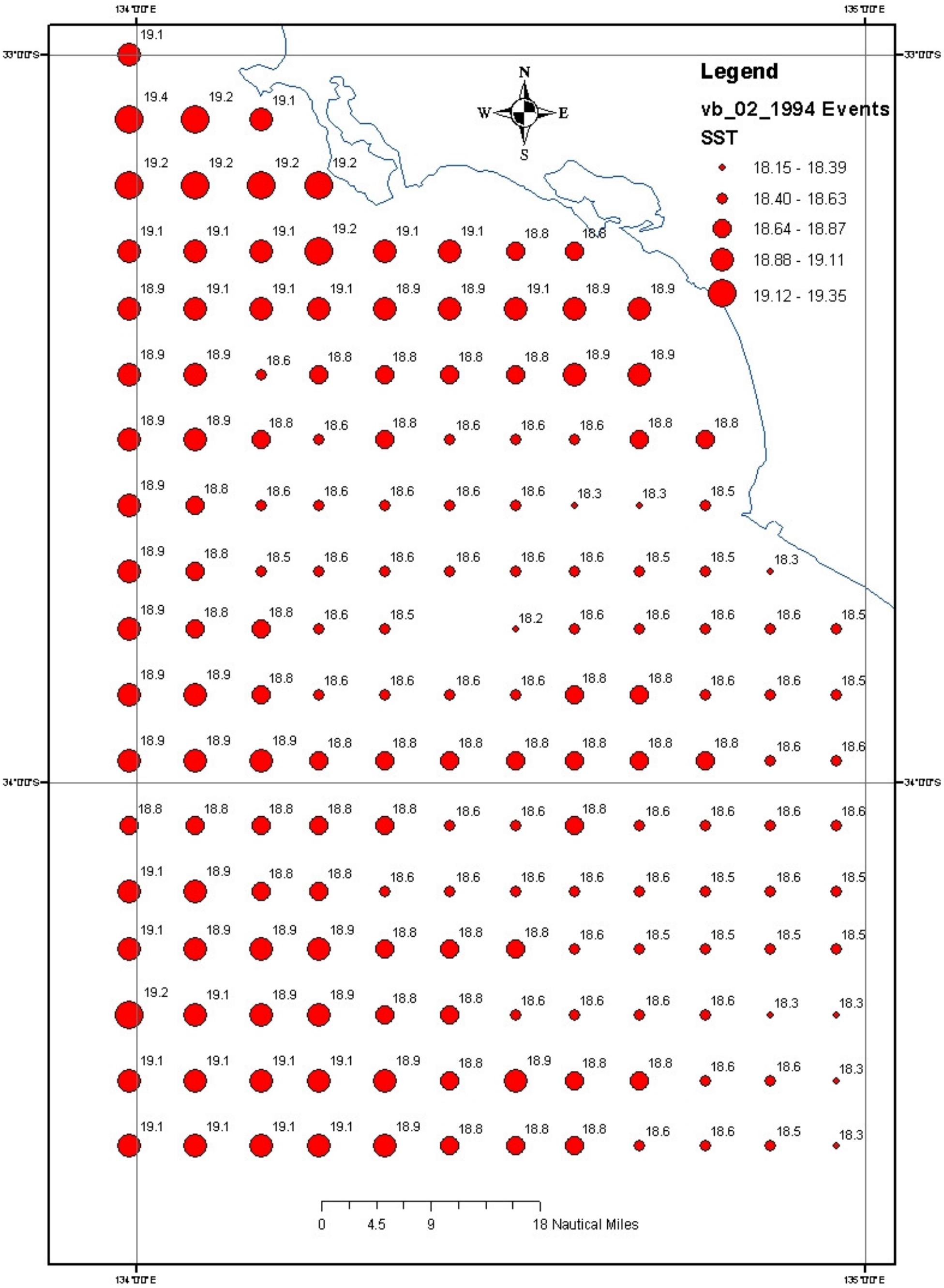


Figure 6.15: West Coast AVHRR SST February, 1992. Data provided by NASA.

The distribution of the SST data was not normally distributed and was subjected to a distribution free bootstrap simulation to determine mean and standard errors. The relationship between SLH and mean SST was fitted to a linear regression using the 14-year data set (Figure 6.16). The regression explained 39% of the variance with coefficients being 12.22 ± 2.56 and 7.33 ± 2.65 for intercept and slope, respectively.

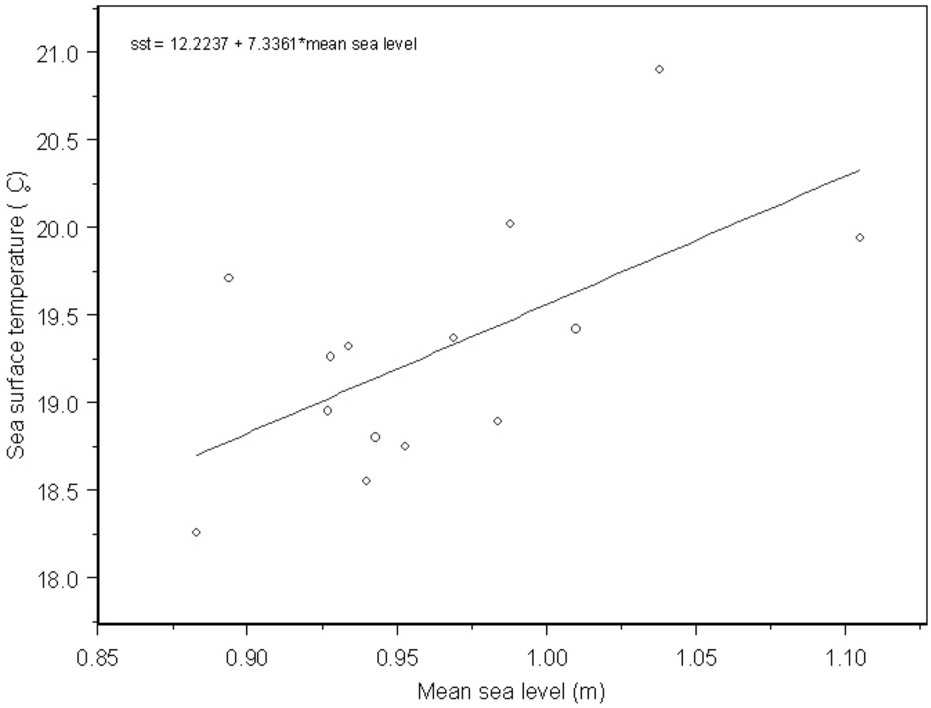


Figure 6.16: Relationship between mean SLH (m) at Thevenard and SST (°C) in the Venus Bay region, 1990-2003.

The results indicate that SLH has an influence on SST and that the SST negative anomaly in 1992 was associated with the Southern Oscillation Index (SOI-an index of Southern Oscillation/El Nino (ENSO) events) in southern Australia. The results provide support to hypotheses that the collapse of the West Coast fishery in 1993 may be associated with cold water impact on larval survival or unfavourable advection of larvae to inshore prawn nurseries through divergent currents.

6.4 Preliminary study of a spawner-recruit relationship (SRR) and influence of the environment on recruitment in the West Coast prawn fishery

6.4.1 Background

Recruitment is defined as the incorporation of new individuals to the population as a consequence of success in reproduction. It is relevant because it implies population sustainability and production of biomass (see., Hilborn and Walters 1992). The determination of the relationship between spawning stock and recruitment, as well as, the understanding of the influence of environmental variation on recruitment is a fundamental problem in fisheries science (Ludwig and Walters 1981, Hilborn and Walters 1992). Despite the economic importance of penaeid fisheries, little information has been produced on SRR relationships in fisheries. For example, Ye (2000), in a review of global stock-recruitment relationships in penaeids, was limited to 8 fisheries, 2 of which were from Western Australia. As late as 1985, it was widely held that penaeid fisheries showed weak relationships between stock and recruitment. Traditional fisheries theory postulated that penaeid prawns with high fecundity and short life spans were not susceptible to recruitment overfishing, (Garcia 1983,1985). The traditional view was that exploitation would never reach such a low level whereby recruitment overfishing occurred, as fishing operations would not be commercially viable at such low levels of stock. Furthermore, in the past, the general view was that environmental variation had the strongest influence on recruitment and most research was focused on studies of the influence of environmental variation on recruitment. However, over the last 15 years it has been demonstrated that penaeids are susceptible to recruitment overfishing (see e.g., Penn and Caputi 1985, 1986, Penn *et al*. 1989, 1995, 1997, Caputi 1993, Courtney and Cosgrove 1995, Gracia 1996, Wang and Die 1996, Hannah 1999, Ye 2000, Die *et al*. 2001, Rodriguez and Arreguin-Sanchez 2003).

Due to the lack of clear SRR in penaeids in the past, management has in most cases proceeded on the premise that recruitment overfishing will not occur and that the annual variation in recruitment levels is the result of environmental factors. This widely held view has been supported by a large number of studies which was reviewed by Garcia and Le Reste (1981) and Garcia (1983, 1989) which produced models for predicting recruitment based on environmental factors (e.g., rainfall, temperature, river outflow etc). Garcia (1983) found that none of the available data provided a satisfactory example of a penaeid SRR or recruitment overfishing in penaeid fisheries. However, Penn and Caputi (1986) were able to provide the first convincing evidence of a spawner-recruit relationship (SRR) in penaeid fisheries while Wang and Die (1996) and Die *et al*. (2001) showed that tiger prawn stocks in the Northern prawn fishery were over-exploited (recruitment overfishing) from the mid-1980s.

Carrick (1996) used fishery-independent trawl sampling data to demonstrate the influence of spawners and water temperature on western king prawn recruitment in Spencer Gulf and suggested that a spawner threshold level (limit threshold) be adapted by management to reduce the risk of recruitment overfishing. However, the model developed by Carrick was constrained by small contrast in variates and insufficient time series of data.

Most studies on SRR in penaeid fisheries have used fishery-dependent catch and effort data with CPUE and processor grades as stock and abundance indices. Few fisheries have reliable long term catch and effort and size composition data at spatial and temporal scales required for the determination of SRR. There are numerous types of stock recruitment curves described in the literature, mostly of exponential (or asymptotic) form. Caputi (1988), Hilborn and Walters (1992) and Quinn and Deriso (1999) provide excellent reviews on the subject. The most frequently used SRR models detailed in the fishery literature are the

Ricker (1954) and Beverton-Holt (1957) models. The Beverton and Holt or BH model is of the following form:

$$R = aS/_{b+S}$$

where *R* is recruitment, *S* is the spawning stock, *a* is the maximum number of recruits produced, and b is the spawning stock required to produce (on average) a recruitment equal to *a/2* and the initial slope (maximum recruits/spawner) is *a/b.*

The basic property of the BH curve is that recruitment constantly increases toward an asymptote as spawning stock increases. The BH curve can be parameterised in a variety of ways as outlined in Hilborn and Walters (1992), Mace (1999) and Mace and Sissenwine (1993), among others. The BH stock-recruitment curve is based on the assumption that juvenile competition results in an increasing mortality rate with increasing numbers in the same cohort. Ricker (1954) proposed a method that is the most frequently used in fishery science and is as follows:

$$R = S \times \exp(a - bS)$$

where *R* is the recruitment, *S* is the spawning stock size, *a* is the initial slope of the curve, and *b* is the value of *S* at which *R = S*.

Unlike the BH curve, the Ricker model shows declining recruitment at high stock sizes. The biological assumption behind Ricker's model is that the mortality rate of eggs or juveniles is proportional to the initial cohort size. The implications of the SRR for fishery management are most important. The relationship can be used to determine the risk of recruitment decline at different spawner abundance levels and to determinate optimum harvest rates, providing auxiliary parameters are known (e.g., initial abundance, M, F, q), (see Walters 1981, Walters and Ludwig 1987).

SRR can incorporate environmental variability, as documented by Penn and Caputi (1986). They noticed two strong outliers in the SRR relationship in the Exmouth tiger prawn (*Penaeus semisulcatus*) fishery, Western Australia, which was associated with cyclones (rainfall). The assumption was that the amount of rainfall (an indicator of cyclone disturbance) had an effect on the survival of juveniles in prawn nurseries. The Ricker model can incorporate environmental variables as follows:

$$R = S \times \exp\left[a - bS + c(E - \bar{E})\right] + w$$

where E is an environmental factor (e.g., temperature), *c* is a coefficient expressing the magnitude of its effect, $E - \bar{E}$ is indexed environmental variation and w error.

Any number of variables can be added, however, a large time series of data is necessary as a few outliers associated with some environmental variation may dominate the relationship and there is a possibility of model over-fitting with no predictive ability.

Benchmark studies of modelling SRR and RSR are those by Penn *et al*. (1995) and Caputi *et al*. (1998) who used commercial logbook data to determine an SRR for Western Australian prawn fisheries and examined the influence of cyclones. They based the SRR on a log-transformed Ricker model. Using data from the Shark Bay prawn fishery resulted in the following Ricker SRR for the brown tiger prawn (*Penaeus esculentus*):

$$R_t = 2073S_{t-1}\exp(-0.0911S_{t-1})$$

where S_{t-1} is the spawning index in year $t-1$ and R_t is the recruitment index of the following year. The SRR explained about 50 % of the variance in recruitment during the period 1965-1994. Unlike Exmouth Gulf, there was no relationship between cyclone disturbance (measured by rainfall) and subsequent recruitment to the fishery, (cf. Penn and Caputi 1986).

Penn and Caputi (1995) examined SRR and RSR in the Exmouth tiger prawn fishery (*Penaeus esculentus*). The authors based the spawning index on commercial CPUE during August-October from 1970-1982 and on trawl surveys on the main "spawning grounds" in October using an area swept estimate for the period 1982 to 1989. Recruitment was based on commercial CPUE from April-June and rainfall was incorporated in the model to reflect the effect of cyclones on recruitment. The fitted SRR was as follows:

$$R_t = 58.6S_{t-1} \times \exp(-0.0229S_{t-1} - 0.0035J_t + 0.0043F_t)$$

where S_{t-1} and R_t are the recruitment and spawning indices respectively, and J_t and F_t are the rainfall (mm) occurring in January and February, respectively. The authors found that both rainfall coefficients were statistically different from zero and the density-dependent parameter estimate (0.0229) was not significantly different to zero.

Die *et al*. (2001) provide a detailed report on regional SRR for tiger prawn species in the Northern Prawn Fishery. They used the Ricker model based on an estimation of spawner and recruits from a generalized version of virtual population analysis when recruitment cannot be treated as a single pulse. Two types of Ricker model were fitted to the data:

1. a model with an autoregressive component
$R_t = a_1 S_{t-1}\exp(-b_1 S_{t-1}) + c_1 R_{t-1,}$

2. a model with a cyclical component
$R_t = a_2 S_{t-1} e^{-b_2 S_{t-1}} + d_2[\cos(h_2 t - k_2)]$

where a_1, a_2, b_1 and b_2 are the parameters of the Ricker type model, c_1 is the autoregressive parameter, d_2 represents half of the amplitude cycle and the parameter h_2 defines the period of the oscillation $(2\pi/h_2)$.

For a Two-stock model, the autogressive stock recruitment relationship explained 49% of the variation in recruitment for *P. esculentus* and 35% for *P. semisulcatus*. The cyclical model explained a greater percentage of variance for both species with 64% for *P. esculentus* and 53% for *P. semisulcatus.*

Caputi *et al*. (1998) found that for western king prawns (*Melicertus latisulcatus*) in Shark Bay, Western Australia, the spawning stock was not significantly related to recruitment. Caputi *et al*. point out that western king prawn in Shark Bay are resilient to recruitment overfishing and do not show a significant SRR, in contrast to the tiger prawn stocks where recruitment overfishing has occurred.

The authors claim that western king prawns are more resilient to recruitment overfishing than tiger prawns due to the following factors:

- Less aggregation of spawning stock
- Less vulnerability to trawling owing to nocturnal behaviour (see Penn 1984).

- A lower level of fishing between recruitment and start of the spawning period.

Research has shown that there are significant genetic (and environmental differences) between the king prawn stocks in Shark Bay and Spencer Gulf, . Furthermore, research on spatial distribution and prawn dispersal patterns in Spencer Gulf and the West Coast demonstrate a high degree of aggregation. King prawns in the colder waters of South Australia have different life history traits to the population in Shark Bay. For example, the life span of king prawns in South Australia is longer and spawning is seasonally restricted. Additionally, the natural mortality of juvenile and adult phases of king prawns in South Australia has been shown to be lower than in warmer water penaeid fisheries which have been documented in the literature. Hence, it would not seem appropriate to generalize research findings for king prawns across fisheries.

Recruitment may be largely independent of stock as the fishery develops (low exploitation) but experience has shown that fisheries will reach the point where recruitment begins to drop due to overfishing. Unfortunately, with powerful fleets, stock reduction may occur well before the problem is recognized in fisheries which are not routinely monitored and experience has shown that it is most difficult to convince industry to reduce exploitation when either spawner or recruit levels are low.

6.4.2 Methods

Data on mean SLH in February, from the previous year (-1 year lag), was regressed on annual average recruitment (32-34 mm CL) means obtained from ANOVA (see above). A number of non-linear and transformed linear regression models were tested including Ricker, Beverton and Holt, Michelson-Menton and exponential types with results reported for the Ricker model, which has wider application. The Hilborn and Walters (1999) parameterisation was used for the non-linear regression of spawners on recruits (2 parameter, a and b) , and a 3-parameter model incorporating indexed SLH where sea level index was based on SLH value-mean SLH for each pair of spawner and recruit variates. The models were:

1. Ricker 2-parameter model

$$R = S \times \exp(a - bS)$$

2. Ricker 3-parameter model incorporating indexed SLH as an environmental parameter

$$R = S \times \exp\left[a - bS + c(E - \bar{E})\right]$$

where R are mean recruit number/n mile, S are mean spawner number/n mile, a and b are the slope and capacity parameters, c is a constant and $E - \bar{E}$ is a scaled environmental index based on the difference of the mean, $\bar{E}$. In this application SLH was used as the environmental parameter.

6.4.3 Results

Relationship between sea level height (SLH) and recruitment at Venus Bay

The relationship between SLH and recruitment was examined using January and February SLH data from the NTF Seaframe based at Thevenard. The relationship between January SLH and recruitment was non-linear and not used in the analysis. A linear regression of February lagged (year -1) SLH on annual June recruitment (32-34 mm CL) at Venus Bay was statistically significant ($p = 0.005$, intercept = 0.023 ± 0.005). The regression explained 65.6 % of variation in the data and the results indicate that recruitment increases with SLH (Figure 6.17).

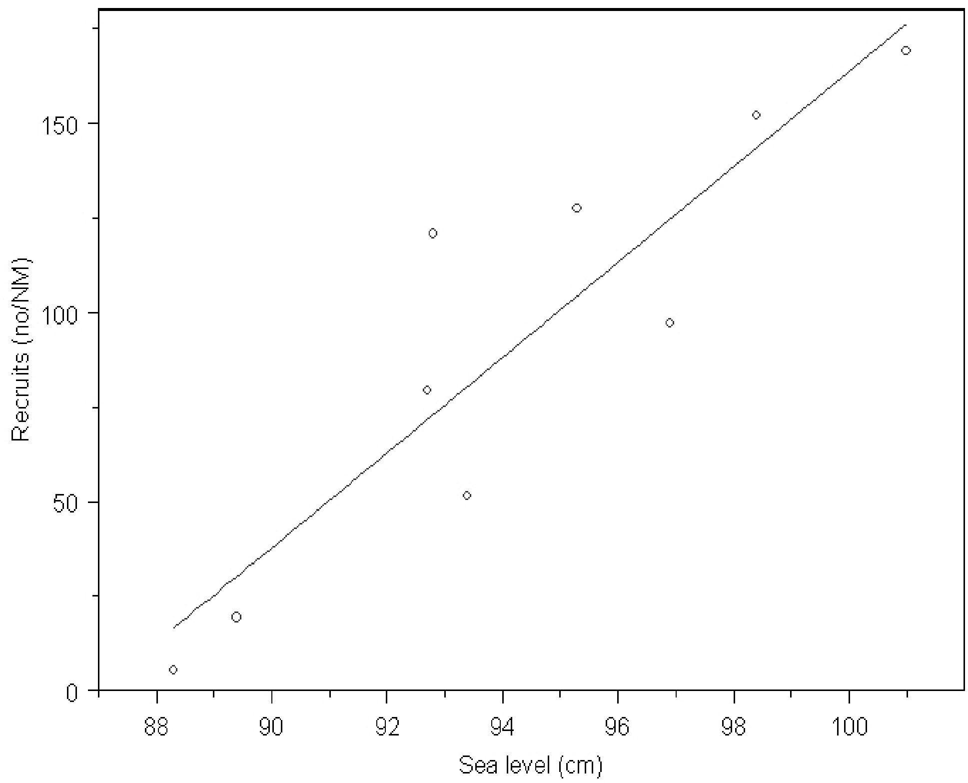


Figure 6.17: Relationship between mean sea level (cm) and recruitment (no/n mile) to prawn trawl grounds at Venus Bay, South Australia.

Modelling the relationship between spawners and recruits with and without SLH.

The relationship between spawners (>43 mm CL) and recruits using the Ricker model with no lag and including indexed SLH indicates that both spawners and SLH influence recruitment (Figure 6.18 A). The model fit to lagged spawners using females >42 and >45 mm CL is illustrated (Figure 6.18 B & C).

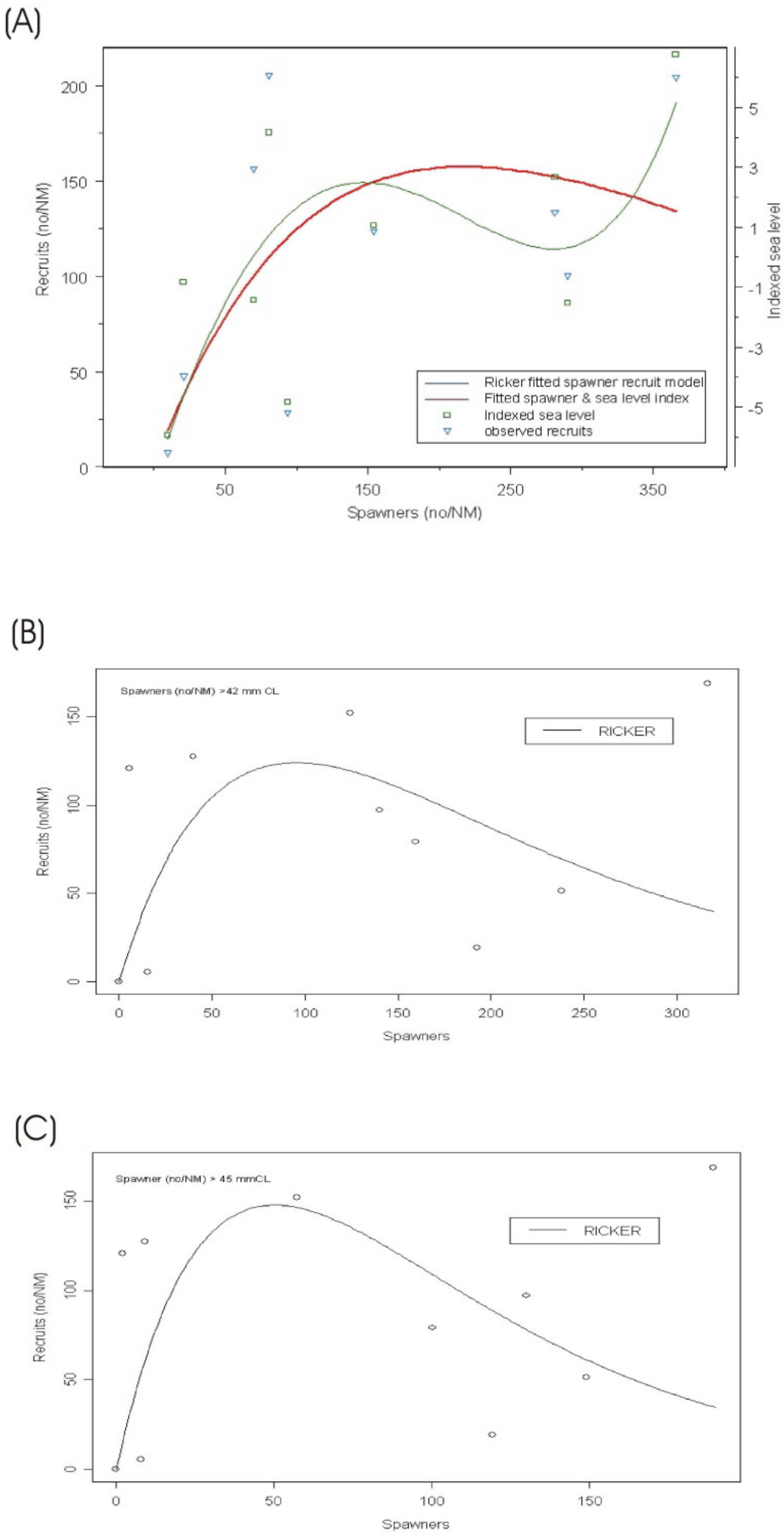


Figure 6.18: Spawner-recruit relationship in the West Coast prawn fishery using the Ricker model - (A) Model fitted using female spawners >43 mm CL & indexed SLH; (B) Fit using lagged female spawners >42 mm CL & (C) using lagged spawners >45 mm CL.

For spawners >43 mm CL with no lag, both a and b parameters were significant (t>2.74, 2.99) with a residual standard error (RSE) of 47.87 (Table 6.1 A). The inclusion of indexed SLH resulted in a reduction in the residual standard error (RSE, 28.53) with all 3 parameters having significant t- values. The results suggest that both sea level and spawner abundance influence recruitment, with recruitment increasing with SLH (*c* = 0.131 ± 0.03). The lagged spawner models for the 3-parameter model were reasonable fits to the Ricker model with sea level (*c*) influence being strong in both cases (Table 6.1 B & C). For the lagged SRR non-linear regressions, the model based on spawner size >42 mm CL was a marginally better fit than lagged spawners >45 mm CL with and without inclusion of indexed SLH. The RSE for the 3-parameter models were 56.3 and 63.5, for spawners>42 and >45 mm CL, respectively.

Table 6.1: Non linear regression estimates of parameters using the Ricker model without and with indexed sea level over different spawner categories.

Parameter	Value	Std. Error	t value	RSE
A: Spawners >43 mm CL with no lag				
a b	1.629 0.005	0.594 0.002	2.741 -2.99	47.867
a b c	2.001 0.007 0.131	0.369 0.001 0.034	5.414 -7.511 3.660	28.532
B: Spawners >42 mm CL and lagged (year-1)				
a b	3.525 0.010	2.326 0.004	1.516 -2.442	68.133
a b c	1.900 0.008 0.168	0.785 0.002 0.086	2.422 - 3.504 1.955	56.262
C: Spawners >45 mm CL and lagged (year-1)				
a b	7.994 0.020	5.260 0.007	1.521 -2.874	72.437
a b c	3.316 0.014 0.167	1.829 0.004 0.095	1.813 -3.100 1.760	63.541

Following the method outlined by Caputi (1993), a linear regression of log(recruits/spawners) on spawners indicated an acceptable fit of parameters to the models with R^2 values ranging from 0.221 to 0.275 when data was forced through the origin (Table 6.2). The R^2 or proportion of variation explained by recruitment ranged from 0.82 to 0.30.

Table 6.2: Linear regression of log (recruits/spawners) on spawners

Model	DF	R^2 Model	a	b	R^2 recruits	RSS Model
Spawner no >43	9	0.221	1.1630	-0.003	0.822	4.593
Spawners lag no >42	9	0 .262	2.2322	-0.008	0.476	13.550
Spawners lag no >45)	9	0 .275	4.6136	-0.015	0.300	18.100

The incorporation of indexed SLH in the linear model without forcing through the origin resulted in a better model fits to all spawner categories with R^2 values of 0.711, 0.596 and 0.659 for spawner no >43, lag no >42 and lag no >45, respectively.

The results indicate that recruitment at Venus Bay is related to both spawners and SLH with the models strongly influenced by the type of spawner index. Outliers from the SRR are attributable to SLH, when SLH is relatively low, recruitment is low and vice-versa (Figure 6.18 A). A preliminary analysis of surface seawater temperature (derived from satellite imagery) indicated that temperature was positively correlated with SLH. Hence, SLH may be an indicator of sea surface temperature with low sea level reflecting colder water which may be an important factor influencing spawning and the supply of larvae to prawn nurseries.

In assuming that SLH is a random event, it would be best practice to maintain spawner levels at around 50-150/n mile depending on the spawner size category, as this would increase the likelihood of strong recruitment when SLH is above average. The fit of the Ricker models indicates that there is a critical level of spawners and that, for lower spawner levels, there is an exponential decline in recruitment.

Additional research is being undertaken on SRR and SRR in both the West Coast and Spencer Gulf fisheries using data from fishery-independent trawl surveys and fishers logbook data based on the methods developed by Caputi (1993), Penn and Caputi (1995) and Die *et al*. (2001).

6.5 Prawn movement at Venus Bay.

6.5.1 Background

An understanding of the spatial distribution, dispersal and movement of prawns is required for effective management of the fishery. The collapse of the fishery at Venus Bay is attributable to a recruitment failure which may be associated with environmental variation (e.g., SLH), spawner depletion or movement dispersal of stock from the region.

6.5.2 Methods

Prawns were tagged in June 1990 using Hallprint streamer tags (type M3, developed by M. Hall and the author) and data from recaptures were used to determine movement vectors at Venus Bay. At 5 sites, a total of 5 000 prawns were tagged inside a closed area to determine the movement dispersal from the inshore region. The Oracle tag database system was used to produce temporal sequences (e.g., intervals of 30-60 days) of recaptures for animation of tag movement using ESRI Tracking analyst.

6.5.3 Results

Recaptures were obtained up to 18 months from release; however, the closure of the fishery to trawling prevented the recapture of tagged prawns. The results show a net offshore movement of prawns in an S/SE direction (Figure 6.19 and Figure 6.20). However, there is a strong variation in individual movement vectors between release locations with sites 5 and 6 showing a net movement offshore in a W/SW direction.

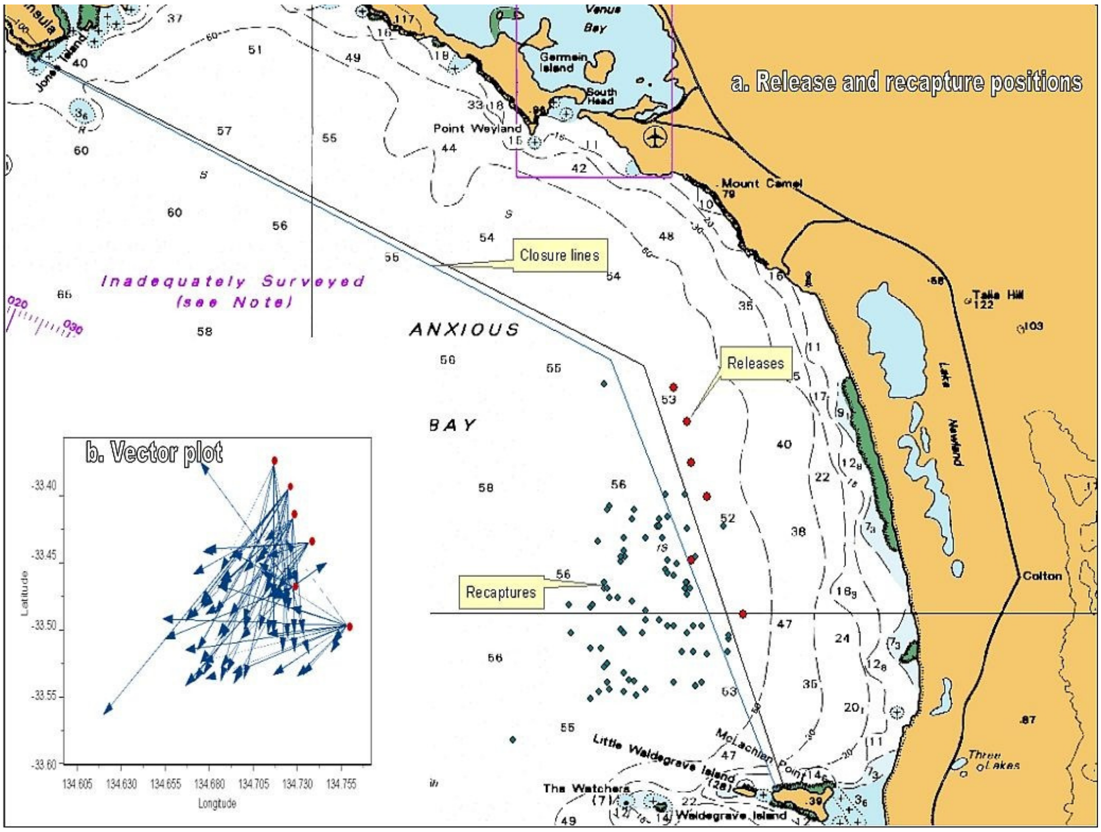


Figure 6.19: Prawn tag release sites at Venus Bay in June 1990 with (a) - fishery closure lines and (b) movement vector plots of prawn recaptures.

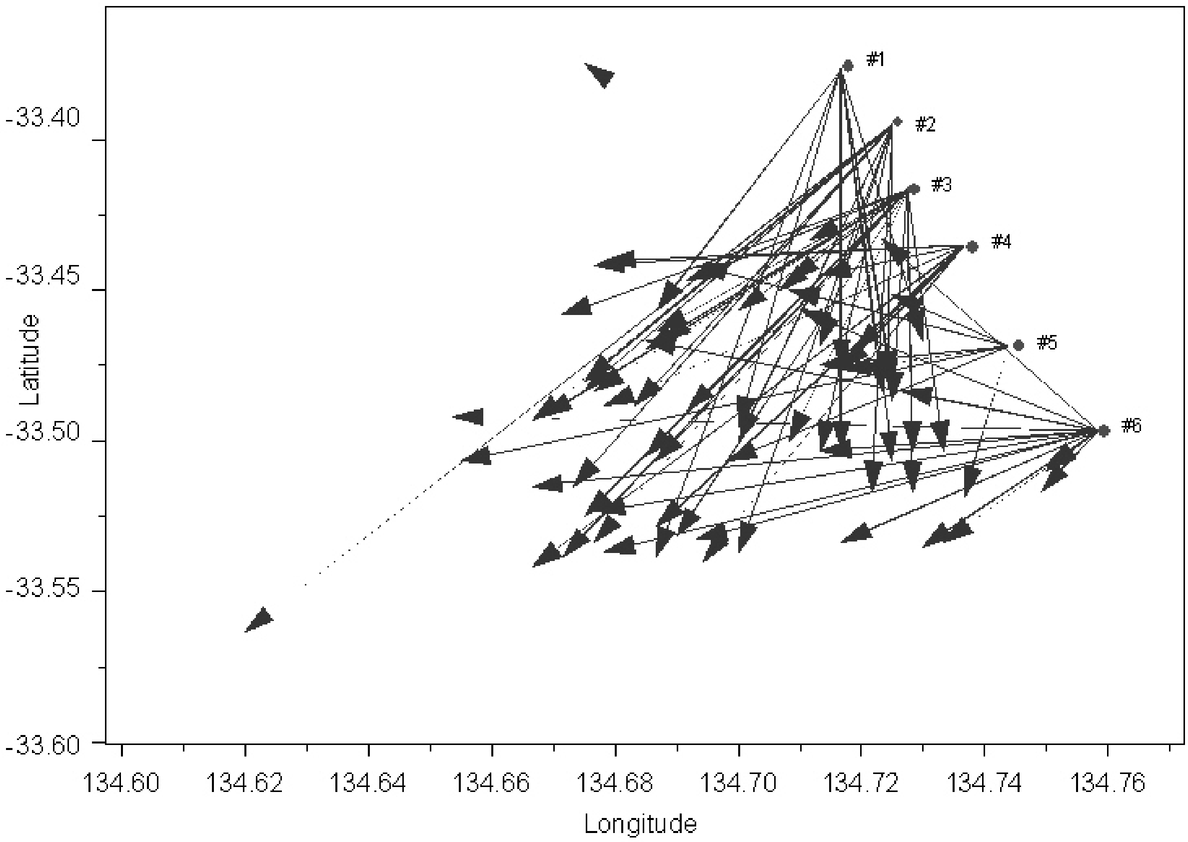


Figure 6.20: Prawn movement vectors derived from mark-recapture experiment in June 1990 at Venus Bay, South Australia.

An example of animation of prawn movement is provided using release recapture data at Venus Bay where tracks from 6 release sites were generated and overlaid with logbook fishing blocks (Figure 6.21).

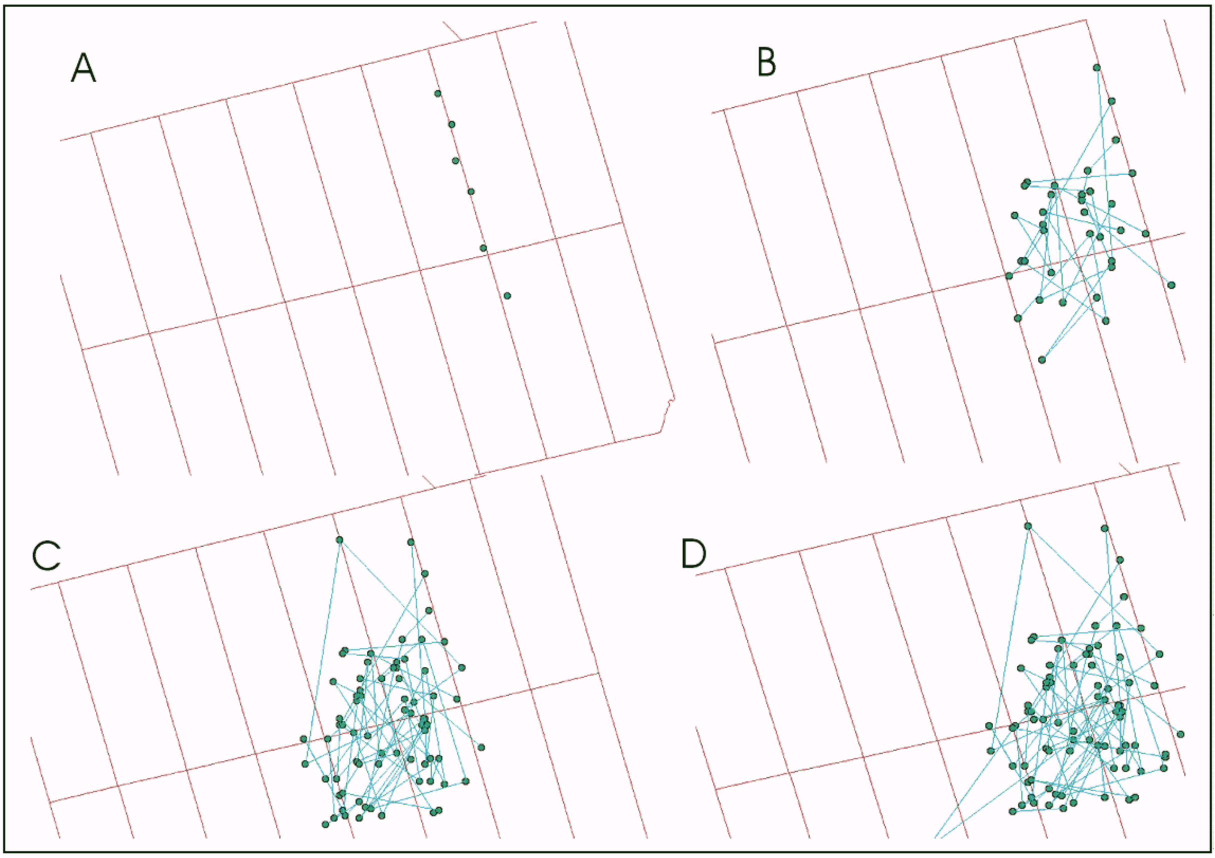


Figure 6.21: Screen dumps of mpeg animation of prawn movement at Venus Bay.

The visualisation of mark-recapture data has allowed a greater understanding of the complex movement patterns of prawn populations in the West Coast and Spencer Gulf prawn fisheries. The research has highlighted gaps in our knowledge of prawn movement. This work could not have been achieved without the support of FRDC as the database systems are the nucleus of the project. With support from industry, it is planned to use mark-recapture in real-time mode to obtain a greater understanding of fine-scale temporal patterns in movement, which will assist in the development of harvest strategies and increase our knowledge of prawn movement dynamics.

7 Spencer Gulf analysis

7.1 Allometry and growth modelling of *Melicertus latisulcatus*

The modelling of growth is most important in fisheries science as model parameters are used frequently in stock assessment. The literature on growth modelling is extensive in mathematical statistics and the fishery literature. Growth can be studied using size frequency samples collected over time and separating cohorts (see Hasselblad 1966, Abrahamson 1971, Pauly and Morgan 1987, Fournier *et al*. 1990, among others). However, the separation of cohorts using normal mixture techniques is problematical in penaeids where recruitment is continuous and where prawn movement confounds population size structure. Furthermore, as cohorts merge, the separation of normal mixtures based on input parameters (i.e. mean and standard errors) for maximum likelihood estimation can be subjective and lead to gross errors in the derivation of growth parameters. Mark-recapture is a more reliable method for the estimation of growth parameters providing releases (and recapture) are spatially representative, spans over season and years and the complete size range of prawns in the fishery. Surprisingly, there are few intensive studies (>2 000 release-recapture pairs) of penaeid growth using mark recapture in Australia where prawns have been tagged to incorporate the effects of location, season and size of prawns on growth.

The scholarly literature relating to periodic regression and circular statistics consists of Bliss (1958,1970) and Batschelet (1981) which are the most relevant for linear model applications. Among classic studies in modelling growth using mark-recapture are Fabens (1965), Sainsbury (1980), Kimura (1980), Schnute and Fournier (1980), Schnute (1981), Maller and deBoer (1988), Francis (1988), James (1991), Ratkowsky (1983,1986), Palmer *et al*. (1991), Kirkwood and Somers (1985), Wang *et al*. (1995) and Wang (2000). A major problem in modelling penaeid growth in the past has been the lack of a seasonal component in fitting models. The von Bertalanffy growth model has received extensive criticism in the literature (Roff 1980, among others). However, it is most extensively used in fisheries research particularly in yield estimation and for estimating mortalities (see Gulland 1983, Ricker 1975, Hilborn and Walters 1992, Quinn and Deriso 1999, among others). Hence, estimation of reliable growth parameters are needed as input parameters for developing harvest models and fishing strategies.

Background studies by the author in the 1980's using cohort analysis (NORMSEP) from size frequency samples collected in Gulf St Vincent indicated that *M.latisulcatus* had strong seasonal growth and did not conform to the conventional von Bertalanffy model in that there was no strong evidence of decrease in growth rate over the commercial sizes captured. Most importantly, the mixture analysis indicated that there were at least 3-4 cohorts in the population which may represent age classes; however, to conclusively prove a lifespan of > 3 years would require extensive tag mark-recapture studies with recapture periods up to 2.5-3 years. Subsequently, mark-recapture studies were undertaken and data fitted to a seasonal linear model that proved to be a reasonable fit to the data (Carrick and Correll 1989). However, the data was constrained by limited size distribution of release and recaptures and short (<1 year) release periods (or time at liberty).

An extensive release-capture field study was implemented in 1986 for Spencer Gulf with strong collaboration and support from industry. The field program had a long term objective and aimed at releasing and capturing prawns over more frequent time intervals (months, years) to obtain a better spread of prawn sizes and to determine area, seasonal and annual differences in growth patterns and the influence of covariates (e.g., water temperature). The study tested both linear and non-linear growth models with the non-linear model based on the von Bertalanffy with re-parameterisation. In general, the von Bertalanffy (VB) assumes that growth is slower at larger size or that rate of growth, K is size-dependent with the growth rate constant reaching asymptote at maximum possible size termed L_∞.

von Bertalanffy models

The model structure is based on the following structure:

$$L_t = L_\infty (1 - e^{-k(t-t_0)})$$

$$L_t = L_\infty (1 - e^{-k(t+swing\,(\sin(\theta-\phi)))})$$

where L_t is length

L_∞ is the length at infinity or maximum attainable length (or alpha)

k is the growth rate constant (or beta) at which growth reaches L_∞

The growth increment in length ΔL between the time tagged (t_1) and recaptured (t_2) is as follows:

$$\Delta L = L_{t_2} - L_{t_1}$$

Hence, the modelled growth increment is:

$$\Delta L = (L_\infty - L_{t_1})(1 - e^{-k\Delta t})$$

The Δt, or time difference between release and recapture is expressed in circular statistics and is a harmonic component which tracks seasonal oscillations in growth. Bliss (1970) and Carrick and Correl (1989) provide a background to seasonal harmonics using linear model applications. Hence, the von Bertalanffy seasonal model can be parameterised as:

$$\Delta L = (L_\infty - L_1) * (1 - e^{-k*(t_2 - t_1) + swing*\cos(theta_2 - phase) - \cos(theta_1 - phase)})$$

where

$theta_2 = t_2 * 2 * \pi$

$theta_1 = t_1 * 2 * \pi$

$phase = \phi$ or the time of year at which growth reaches its maximum

Weight can be modelled by converting lengths to weight using derived allometric regression estimates (unpublished). The allometric relationships derived were:

$\log weight = -6.705 + 2.764 * length$ .....male

$\log weight = -6.347 + 2.657 * length$ ....female

Linear models

The linear models are based on harmonic regression. However, the harmonic tends to force growth rate to negative value. It is noted that if length of a prawn has a von Bertalanffy growth rate, then weight (cube of length) would follow a Richards curve with a power factor of 3. The Richard curve would be nearly straight over most of the size ranges in the population. The simplest model termed simple linear model (SML) is as follows:

$$\Delta l = \beta_0 + \beta_1 freedom + \beta_2 \Delta(\sin(\theta - \phi)) + error$$

where

$freedom$ is time (in years) from release (t1) to recapture (t2)

θ is time as an angular measure with one cycle per year

ϕ is the time of the year when growth is at its maximum

The SML was enhanced to incorporate a slowing of growth in both length and weight at the larger size, which is effectively a weighting in the linear regression. An additional term (S) was added to the model based on length (or weight). Theoretically, the average weight of the prawn over the growth period should be used but it is more practical to use the prawn's initial length (weight). The model would give a reasonable approximation as long as the growth period is small. The modified linear model (MLM) is described as:

$$\Delta l = \beta_0 + \beta_1 freedom + \beta_2 \Delta(\sin(\theta - \phi)) + \beta_3 S + error$$

where S is the product of the initial weight and the growth period.

7.1.1 Methods

Prawns were tagged in the 2nd and 3rd tail segment using Hall streamer tags (4S and 7S) developed by the late Michael Hall (Hallprint) and the author. The locations of the tag releases are illustrated (Figure 7.1). At tagging, the carapace length (CL) was measured to ± 0.05 mm, prawns were maintained in circulating tanks for approximately 2 hours then released on the bottom using a release cage designed by the author. Prawns were recaptured by fishers or during trawl surveys. Recaptures were measured ashore and information recorded in forms. The screen dump shows the Oracle data entry form for data entry and validation of release-recapture with the tag number being unique (Figure 7.2). SQL Plus was used to produce output reports eg. tag number, sex, release day, release month, release year, initial size (*L1*), recapture size (*L2*), growth, day recaptured, month recaptured and year recaptured.

Release and recapture dates (*t1, t2*) were based on year as *year+(month-1+(day/30)/12)* to derive *theta 1, theta2 = t1, t2*2*3.1416* and *delta sin = sin (theta2)-sin (theta1)* and *delta cos = cos (theta2)-cos (theta1)*, (see above). Data from 1,880 male and 922 female prawn release-recapture pairs were used from the 3,500 sets of data following the elimination of recaptures that had a release period of <30 days. Data was subjected to linear and non-linear programs as described above. The code was written in Genstat 5. The program plotted residual-fitted values and output extreme outliers. All recaptures ≤30 days were omitted due reduce problems associated with moult phase variations and indeterminate growth.

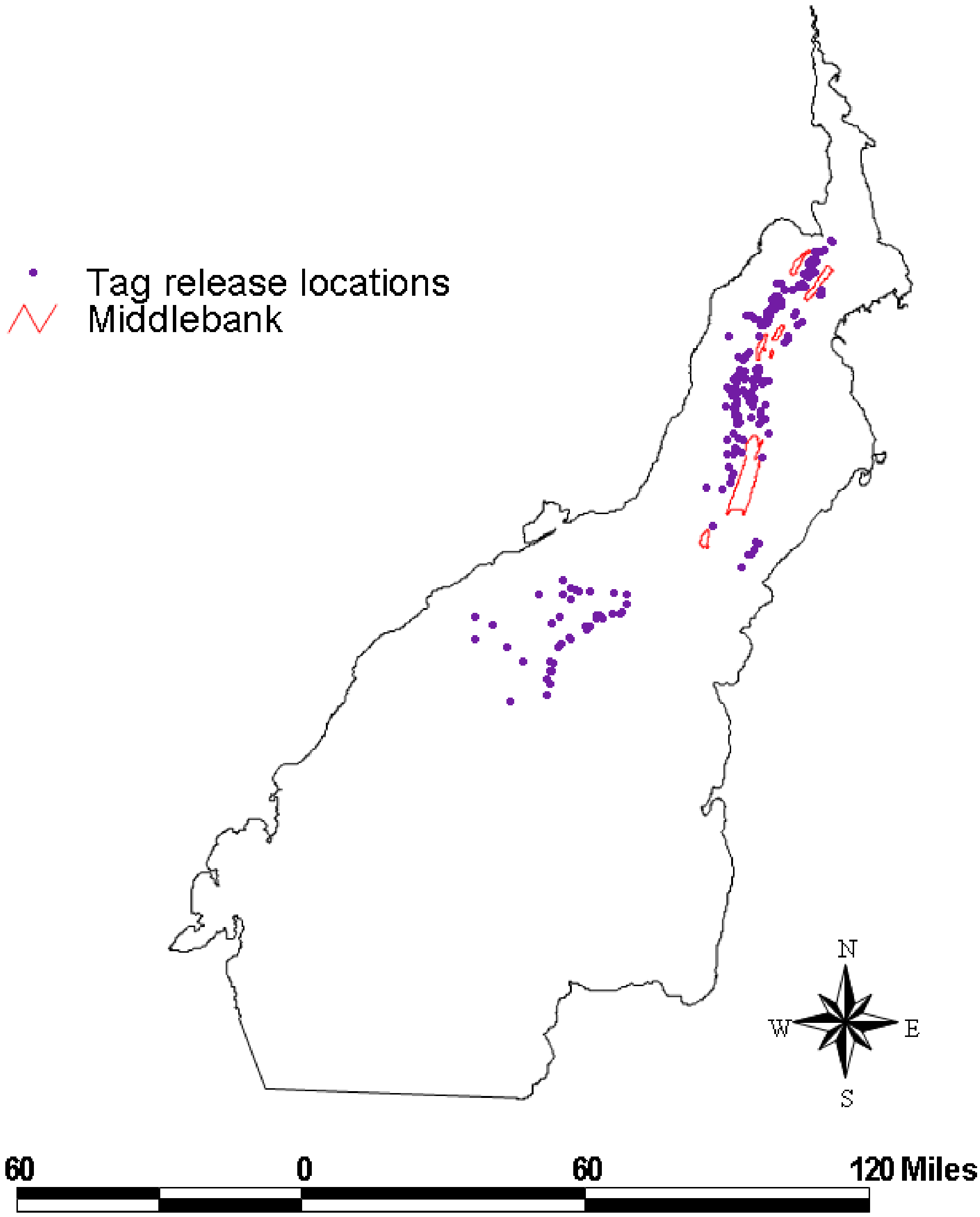


Figure 7.1: Tag release locations in Spencer Gulf.

7.1.2 Results and conclusions

The longest periods of releases were 835 and 750 days for male and female prawns, respectively. Hence, *M. latisulcatus* has a lifespan exceeding 3 years which is the longest recorded for a penaeid. Figures 7.3 and 7.4 illustrate the size of prawns at release (t_1) and recapture (t_2), which were used in modelling growth. It is evident from the results that the size of recaptures is larger in female prawns. In both sexes there are relatively few larger individuals and a cluster of sizes between 35-42 mm CL which could potentially bias estimates of K and L_∞. Table 7.1 provides estimates of model parameters, standard errors and the percentage variance accounted for by regression.

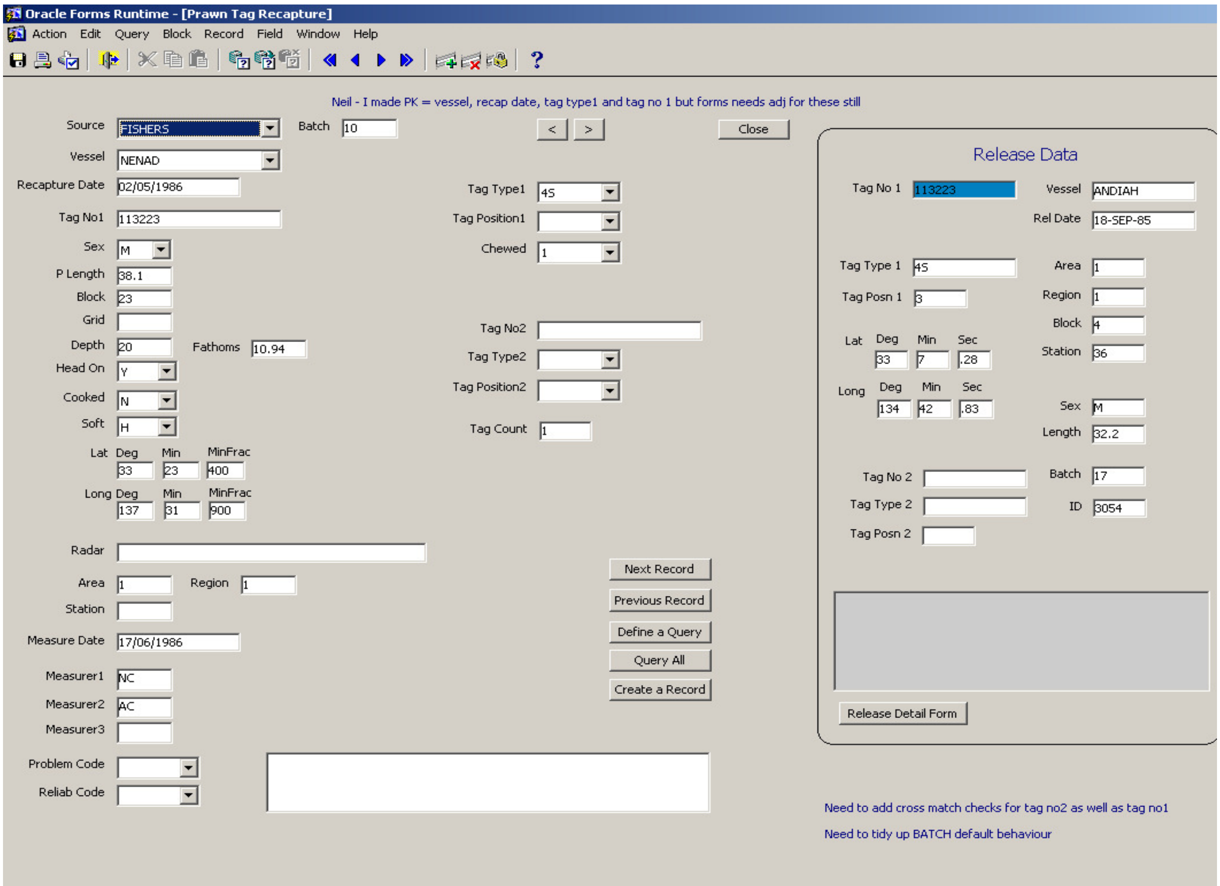


Figure 7.2: Screen dump of Oracle tag database, recapture entry showing release link on the right hand side of screen.

The results show that:

- All models provide good fits to the data.
- The growth parameters are different for males and females. Males grow more slowly and have a different period where growth reaches its maximum (phase) compared to females.
- The MLM and SVB provide most reliable estimates although the bias associated with the SVB is problematical, especially at large size. The W_∞ or alpha estimate (322.8 grams) is relatively large compared to L_∞ which was 63.99 mm CL.
- The periods of maximum growth (or phase) were 2.83 and 2.82 for length and weight of males. The phases for female prawns were 2.82 and 2.9 for length and weight respectively. Hence, maximum growth for both sexes using length and weight models of the VB occurred between the 23-25 March.
- There are advantages to using the MLM for prediction of growth changes in harvest models over the range of commercial sizes of catch of western king prawns in Spencer Gulf.

The L_∞ for length were 46.1 ± 0.27 and 63.99 ± 0.89 for male and female prawns, respectively. The K estimates for length were 0.859 ± 0.024 and 0.612 ± 0.031 for male and female prawns, respectively.

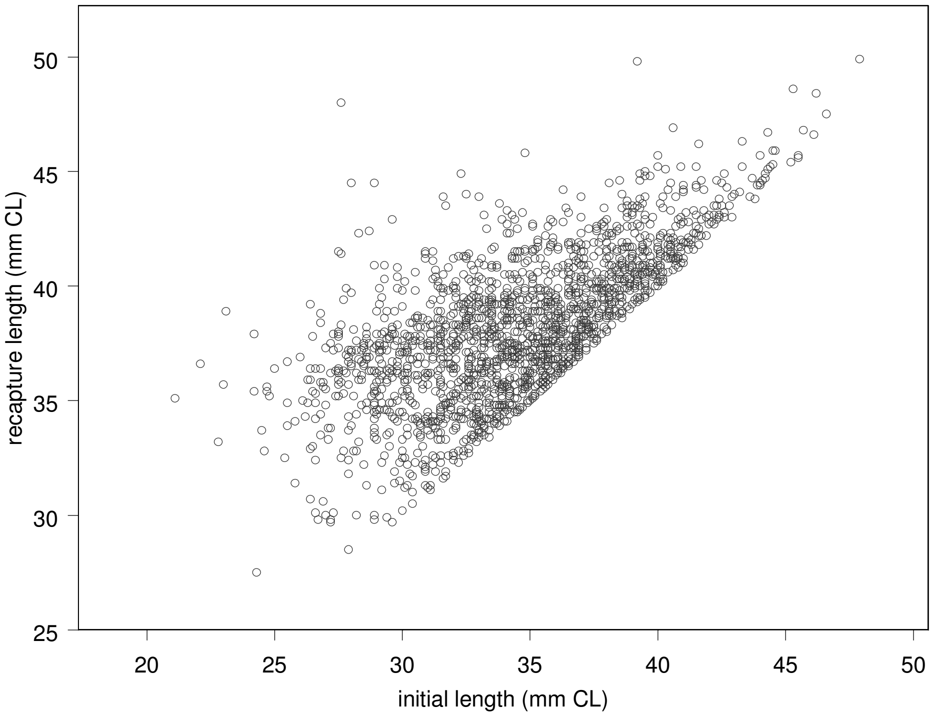


Figure 7.3: Relationship between initial length (mm CL) at tagging and length at recapture of male Melicertus latisulcatus, 1986-1991.

Figure 4: Scatter plot of female *Penaeus latisulcatus* from release to recapture

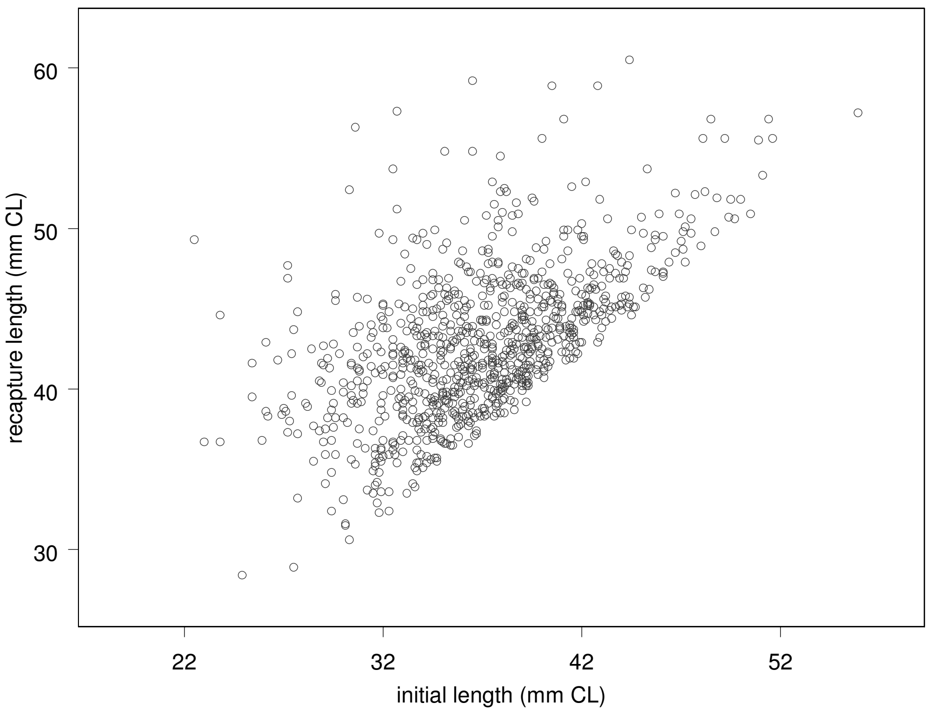


Figure 7.4: Relationship between initial length (mm CL) at tagging and length at recapture of female Melicertus latisulcatus, 1986-1991.

Table 7.1: Summary results of fitting growth models of Melicertus latisulcatus in Spencer Gulf

A: length (mm CL)

Simple linear model-Male % variance = 59.6;Female % variance = 69.4

Variate	Male estimate	Se	t-value	Female estimate	Se	t-value
Constant	0.6017	0.0995	6.050	1.315	0.186	7.05
Freedom	6.7860	0.1420	47.63	10.184	0.230	44.27
Delta sine	0.1797	0.0605	2.97	0.586	0.099	5.90
Delta cos	-1.7105	0.0550	-31.66	-1.564	0.105	-14.89

Modified linear model- Male % v = 78.4; Female % v = 82.6

Variate	Male estimate	Se	t-value	Female estimate	Se	t-value
constant	1.1634	0.074	15.68	1.238	0.141	8.79
freedom	26.224	0.493	53.17	28.994	0.736	39.37
Delta sine	0.2016	0.044	4.55	0.479	0.075	6.37
Delta cos	-1.4768	0.040	-36.95	-1.631	0.079	-20.54
slowdown	-0.6106	0.015	-40.33	-0.518	0.020	-26.29

von Bertalanffy- Male % v = 83.4; Female % v = 82.3

Variate	Male estimate	Se	t-value	Female estimate	Se	t-value
intercept	-0.0249	0.081		-0.749	0.201	
alpha	46.1000	0.268		63.988	0.887	
beta	0.8597	0.024		0.612	0.031	
swing	0.2218	0.004		0.160	0.006	
phase	2.8250	0.028		2.840	0.044	

B: Weight (g)

Simple linear model-Male: % variance = 69.7;Female % v = 82.2

Variate	Male estimate	Se	t-value	Female Estimate	Se	t-value
variate	Male estimate	se	t-value	Female estimate	se	t-value
constant	0.698	0.157	4.45	-0.672	0.352	-1.91
freedom	13.508	0.225	60.17	27.571	0.435	63.42
Delta sine	0.664	0.095	6.97	1.535	0.188	8.17
Delta cos	-3.149	0.085	-36.99	-3.980	0.199	-20.04

Modified linear model- % variance = 75.5;Female % v = 83.2

Variate	Male estimate	Se	t-value	Female estimate	Se	t-value
constant	1.276	0.144	8.88	-0.720	0.342	-2.10
freedom	20.162	0.375	53.80	32.441	0.781	41.55
Delta sine	0.679	0.086	7.92	1.447	0.183	7.91
Delta cos	-2.928	0.077	-37.88	-4.034	0.193	-20.89
slowdown	-0.373	0.018	-21.07	-0.193	0.026	-7.42

von Bertalanffy- % variance = 77.0;Female % v = 82.6

Variate	Male estimate	Se	t-value	Female estimate	Se	t-value
intercept	0.035	0.157		-1.546	0.424	
alpha	60.18	1.590		322.8	66.3	
beta	0.440	0.022		0.101	0.025	
swing	0.225	0.005		0.154	0.006	
phase	2.823	0.030		2.785	0.048	

The model parameters derived in this study are statistically sound with relatively low error. However, more extensive modelling is required using both tag and size frequency data for derivation of spatial differences in model parameters for the influence of environmental variation on growth. Except for the SLM, the models account for >70 % variance in the data. Work by King (1978), Kangas and Correll (unpublished) and Xiao and McShane (2000) report growth of *Penaeus latisulcatus* in Gulf St Vincent (GSV), South Australia. Both studies provide similar results to those obtained from this study and from other work by the author which were done in the GSV prawn fishery (unpublished). Wallner (1985) used tag and cohort data to estimate growth parameters for western king prawn from the South Australian West Coast prawn fishery. However, the number of release-recaptures data for the West Coast study were low (<300), seasonally clumped and there was no seasonal component in the model which would bias growth estimates.

The good fits to data are attributable to an extensive data set obtained from a structured field mark-recapture program undertaken in close collaboration with industry. The data indicates that maximum growth is reached in late March. If the growth phase is approximately normal then one would expect extended growth and increase in the value of the prawn stock after the period in which growth has reached maximum. Allometry and seasonal growth parameters for male and female prawns were used as input parameters for harvest simulations to determine the optimum period to fish different areas of the Gulf.

7.2 Temporal and spatial pattern of prawn catch and effort in Spencer Gulf

7.2.1 Annual trends in catch and effort

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 7.5).

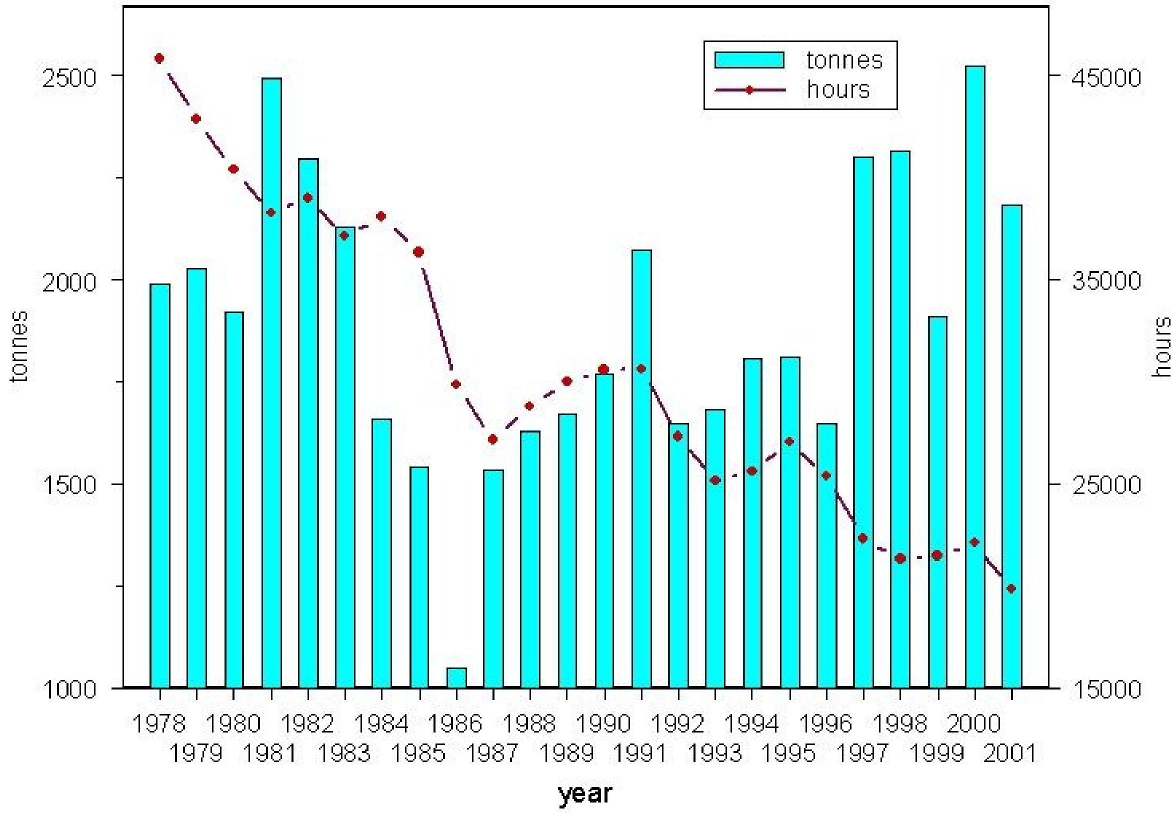


Figure 7.5: Historical trends in western king prawn catch and nominal trawl effort (hours) in Spencer Gulf from 1978-79 to 2001/2002.

High catches over the last 5 years may be due to increased levels of recruitment and "fine-tuning' of harvest strategies. In 1986-87 the catch declined due to low recruitment induced by overexploitation and growth overfishing (Carrick 1996). There has been a substantial decrease in the amount of small prawns landed from 1978-79 to 1998-99 where the percent of smaller prawn categories >20 prawns per pound and 16/20 prawns per lb (head on) has declined from 71% to 28.8 % with a commensurate increase in larger sizes (Figure 7.6).

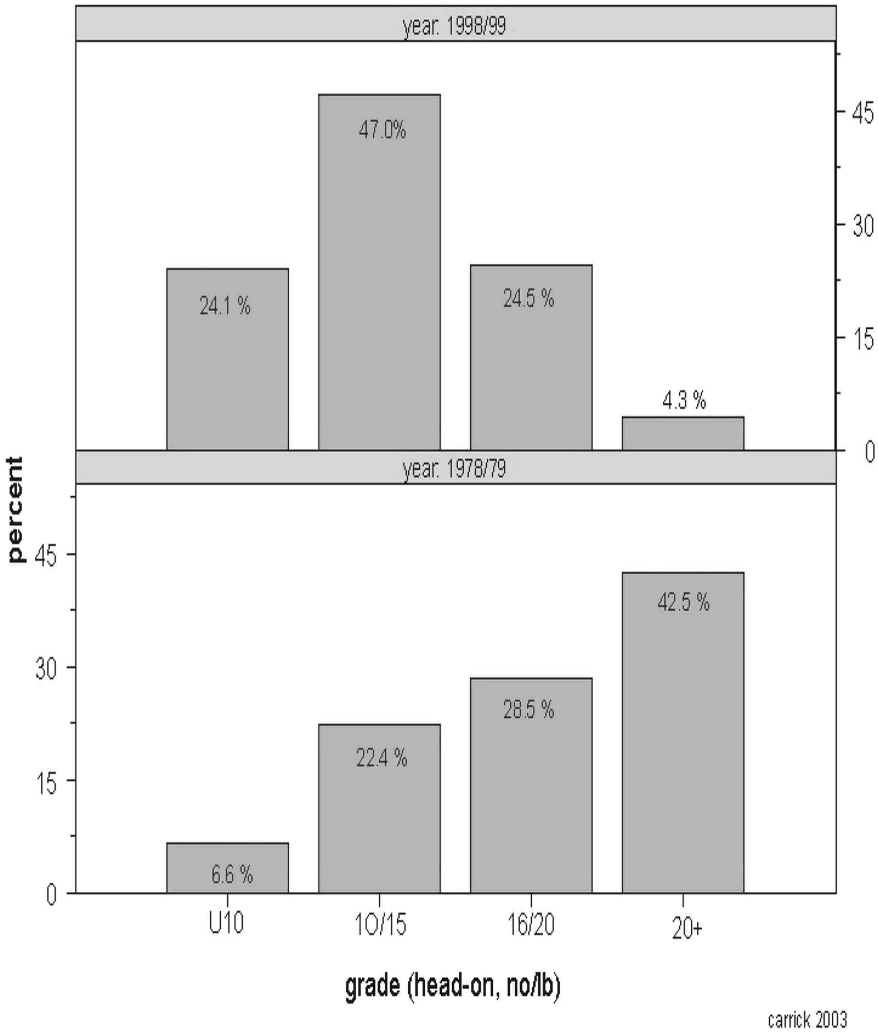


Figure 7.6: Comparison of the size composition of prawn landings in 1978-79 and 1998-99 based on four size grades from large prawns (under 10 prawns/lb) to small prawns (>20 prawns/lb).

Further details on the increase in prawn size composition and benefits of harvest strategies are provided below.

7.2.2 Catch, trawl hours and catch rate by fishing period

Landings in 2001-02 were 2 182 tonnes for 55.5 days or 19 843 hours. Details of recorded catch and nominal trawl hours by period are outlined in Table 7.2. Differences in catches are attributed to different abundance patterns over season and areas. For periods 1 and 2 (termed ‘Pre-Christmas’), 678 tonnes were landed for 19 fishing days with a catch rate of 112.7 kg/h. For fishing from March to June (periods 3-6) over 1 000 tonnes were landed for 36.5 fishing nights.

Table 7.2: Spencer Gulf prawn production over six fishing periods in 2001/2002.

Period	From	To	Days fished	Catch (tonnes)	Hours	Cpue ($kg.hr^{-1}$)
1	15/11/2001	22/11/2001	12	312.8	2,216	141.1
2	9/12/2001	20/12/2001	7	365.6	3,804	96.1
		Total	19	678.2	6,019.4	112.7
3	11/03/2002	20/03/2002	10	288.0	3,662	78.6
4	9/04/2002	20/04/2002	10.5	555.5	3,954	140.5
5	7/5/2002	17/5/2002	10	510.6	3,878	131.7
6	9/6/2002	14/6/2002	6	149.7	2,330	64.2
		Total	36.5	1,503.9	13,824	108.8
1-6		Total	55.5	2,182.1	19,843.4	110.0

The 'triggers' for ceasing to fish an area or move the fleet are determined in collaboration with 6 fishers (CAS) Normally, fishing ceases at a given area when small or sub-optimal prawns are captured, depletion is high and likely to effect the growth (and value) and reproductive potential of stock in a given area and if target catch levels are exceeded. Furthermore, fishing ceases in given areas to allow greater "spread' or dispersal of fleet (and prawns) for successive fishing periods. If recruitment and spawner stock are low, a cautious approach is adopted with delayed harvesting and limits on the number of days fished and the amount of depletion. The fishery is monitored daily and harvest schedules are developed prior to fishing and refined throughout each fishing trip. The amount of fishing is dependent on the distribution and abundance of harvestable stock

7.2.3 Spatial patterns in catch, effort and catch/unit of effort (CPUE) over 2001/2002.

Fishery-dependent catch and effort and size composition data is a major source of information for research and management for assessing the performance of the fishery and for evaluating the benefits of different harvest strategies (e.g., closures).

Commercial logbook data was entered and validated by SARDI. Fishing blocks were digitised from Australian RAN Hydrographical charts (776, 777 & 778) using a CALCOMP digitising board using Arc Info (Figure 7.7). Fishers are required to record detailed spatial information on the location of catch using the fishing block system and GPS bearings (latitude/longitude). There are 127 fishing blocks or irregular polygons with the centroids used in mapping catch, effort and CPUE. The size of the fishing blocks varies, ranging from 7.8 (block 28) to 296 nm2 (block 93). The average area of the polygons is 49 n mile^2 with over 75% less than 65 n mile^2. The above block system was adopted in 1984 and replaced regular grids to better reflect the location of fishing grounds and differences in prawn abundance and size composition. Furthermore, the block system was developed as a tool for implementing dynamic closures to protect small prawns from premature harvesting. Daily logbook data was summarised, which consisted of >50 000 records of catch, trawl hours and CPUE (kg/h) for each fishing block in Spencer Gulf.

The spatial distribution of catch (kg) over each of the six fishing periods in 2001-02 is illustrated (Figure 7.8 to 7.13). For Period 1, the highest catches were from blocks 40 (41.4 t), 50 (38.2 t) and 51 (32.2 t). The catches reflect the implementation of closure strategies over the period where the main Cowell area and grounds north of Middle Bank were closed to trawling to protect small prawns and ensure sufficient egg production. In Period 2, fishing was generally more dispersed within the closure constraints, with highest catches from blocks 38 (66 t), 37 (39 t) and 31 (34 t).

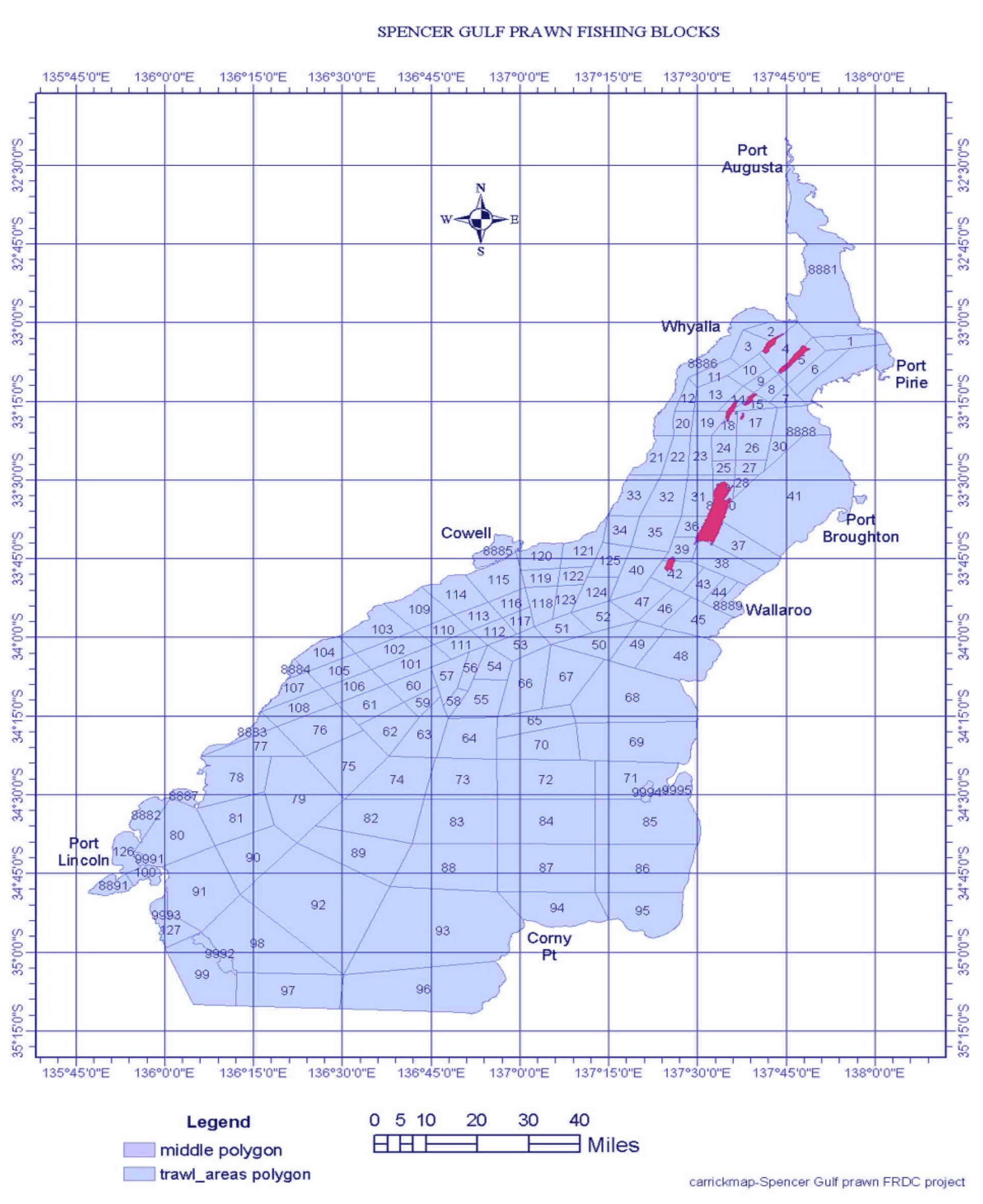


Figure 7.7: Spencer Gulf commercial fishing blocks.

Prawn landings in Period 3 (March 2002) were derived from the southern fishing grounds, when the Wallaroo and northern grounds were closed to protect sub-optimal size prawns and maximise egg production. Highest catches in Period 3 were from blocks 69 (87.2 t), 87 (50 t) and 84 (20 t). In Period 4 the Wallaroo and Cowell grounds were opened with 48 blocks fished over the period in April-May 2002. Highest catches occurred in block 44 (98 t), 38 (94 t) and block 43 (85 t). The highest seasonal catch rate occurred at block 44, at 288 kg/h. In Period 5, an additional area was opened to trawling in the vicinity of Middle Bank, with fishing taking place in 23 blocks. Highest catches in Period 5 were recorded in blocks 35 (75 t), 43 (70 t) and 40 (53 t). In Period 6, relatively low catches occurred due to stock depletion and restriction of effort (days available to fishing) and spatial constraints imposed on fishing due to area closures. Thirty two blocks were fished in Period 6, and the highest catches were from blocks 43 (25 t), 38 (23 t) and 36 (22t).

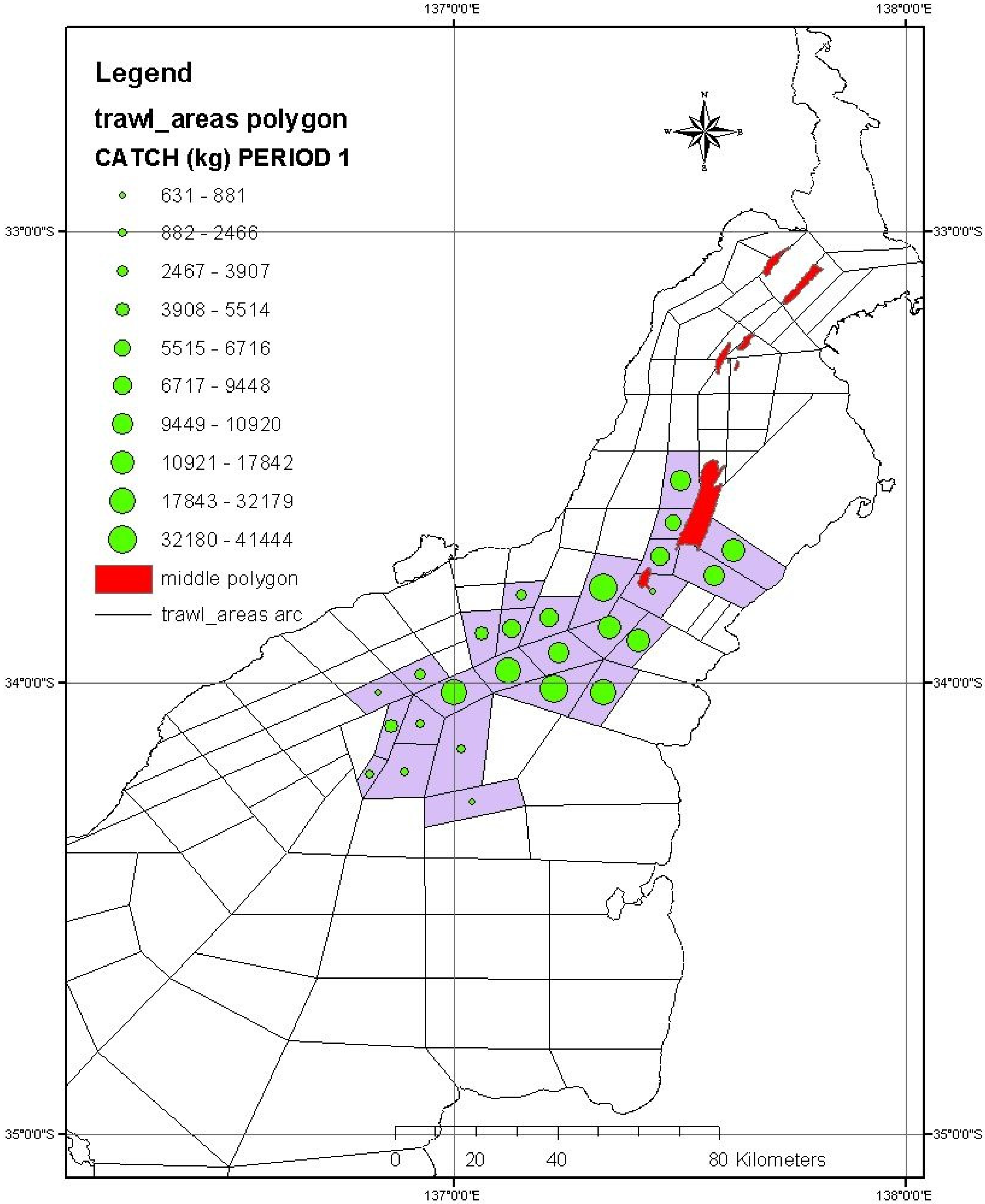


Figure 7.8: Spatial distribution of prawn catch in fishing Period 1, Spencer Gulf, 2001-2002.

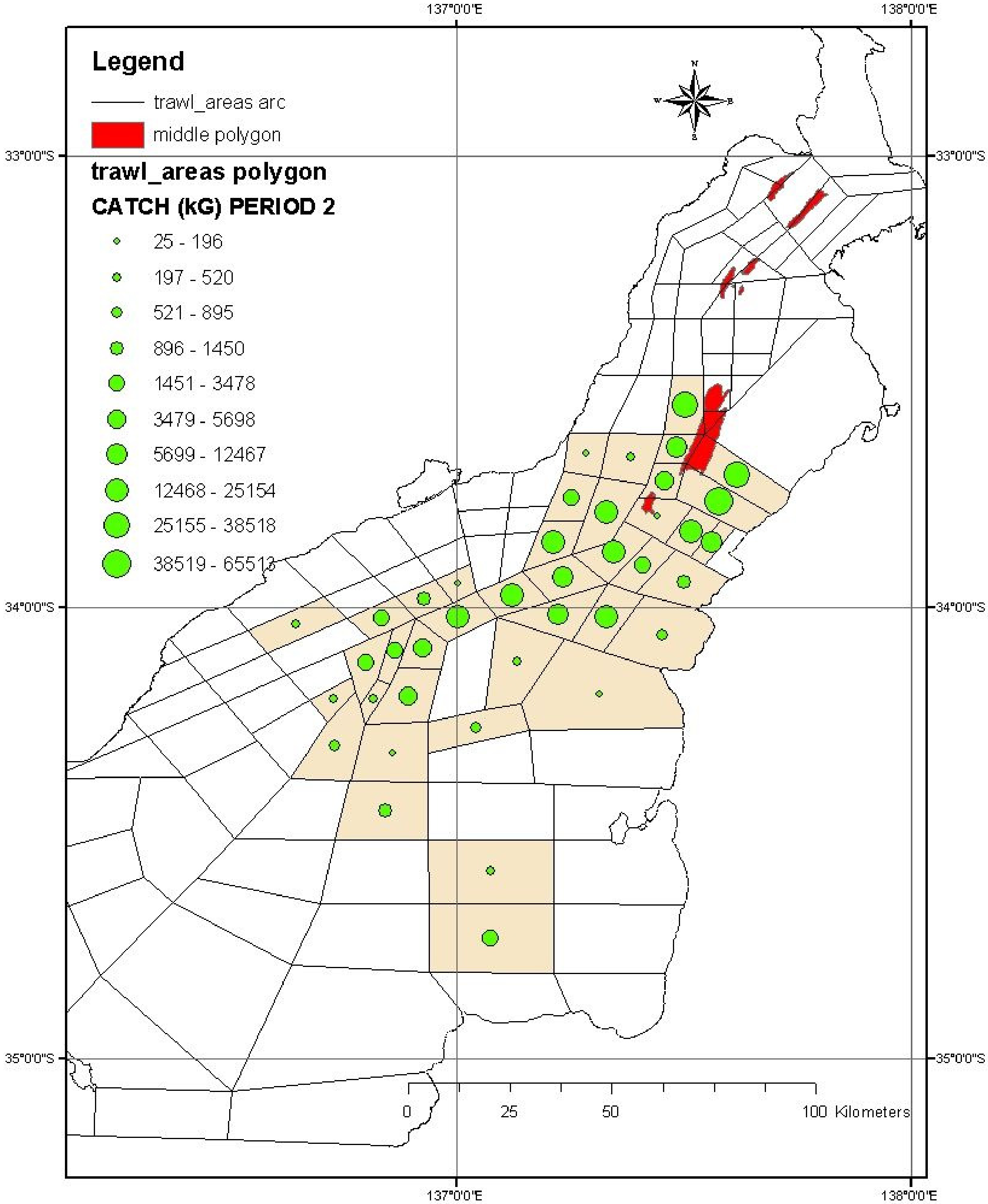


Figure 7.9: Spatial distribution of prawn catch in fishing Period 2, Spencer Gulf, 2001-2002.

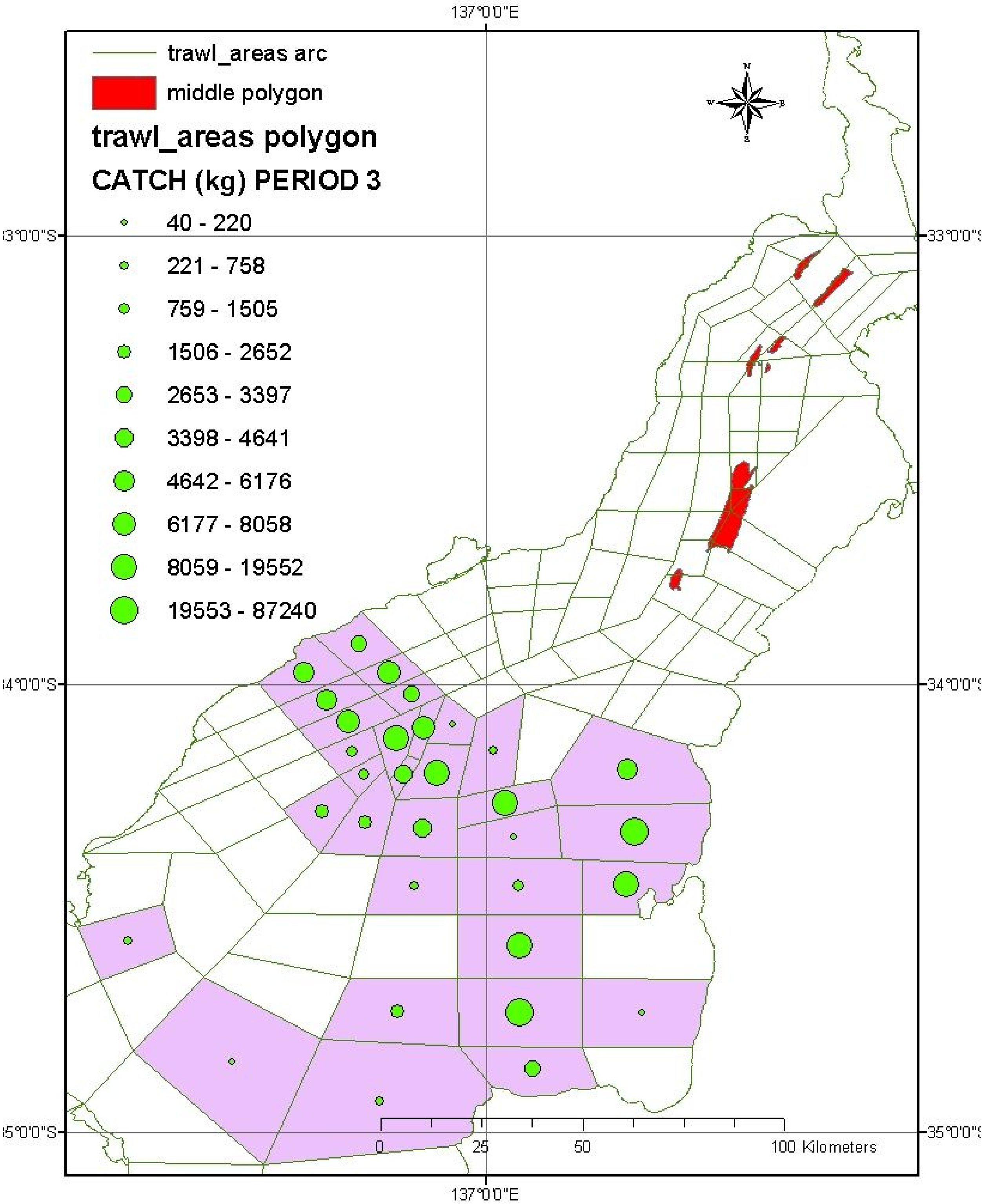


Figure 7.10: Spatial distribution of prawn catch in fishing Period 3, Spencer Gulf, 2001-2002.

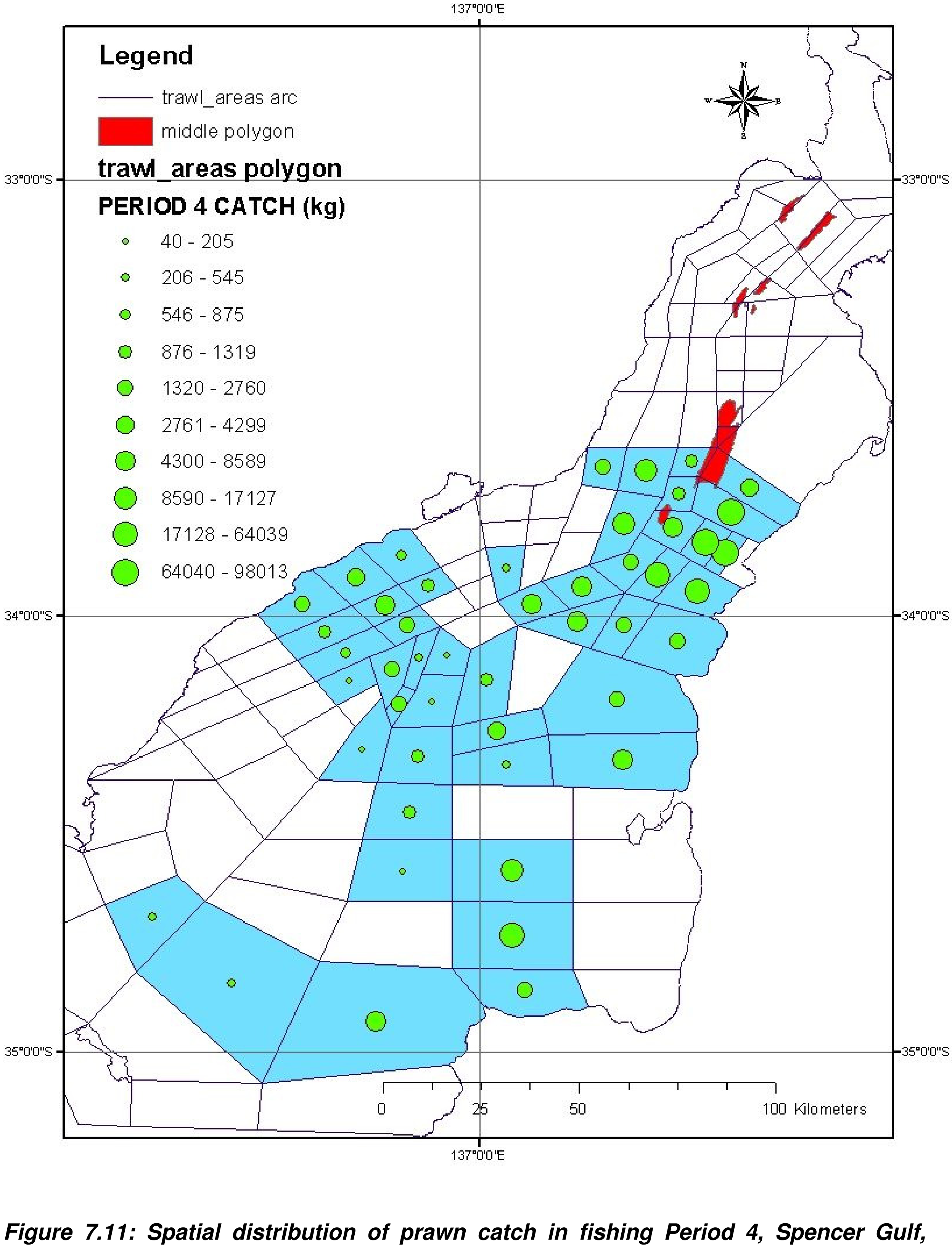


Figure 7.11: Spatial distribution of prawn catch in fishing Period 4, Spencer Gulf, 2001-2002.

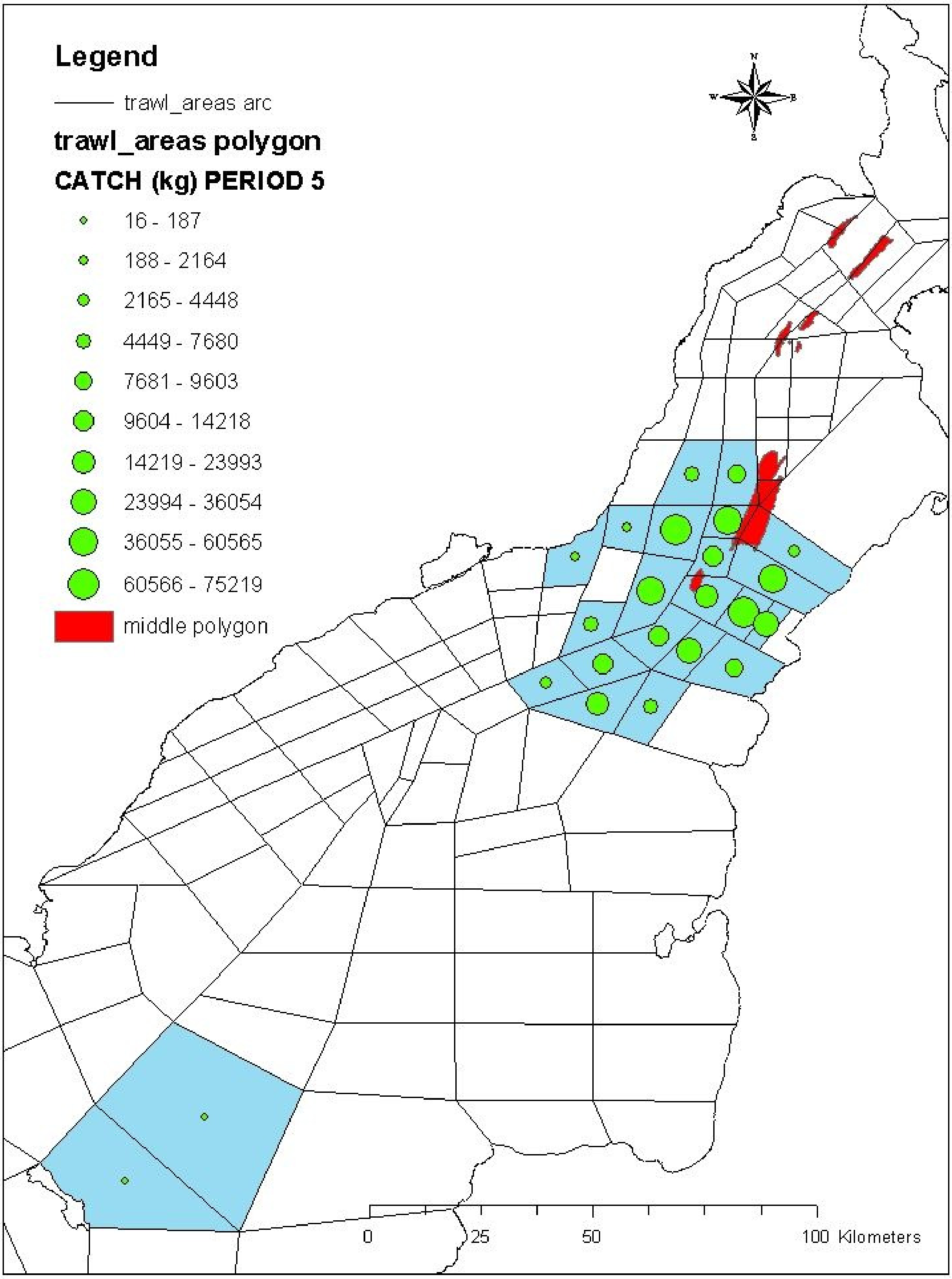


Figure 7.12: Spatial distribution of prawn catch in fishing Period 5, Spencer Gulf, 2001-2002.

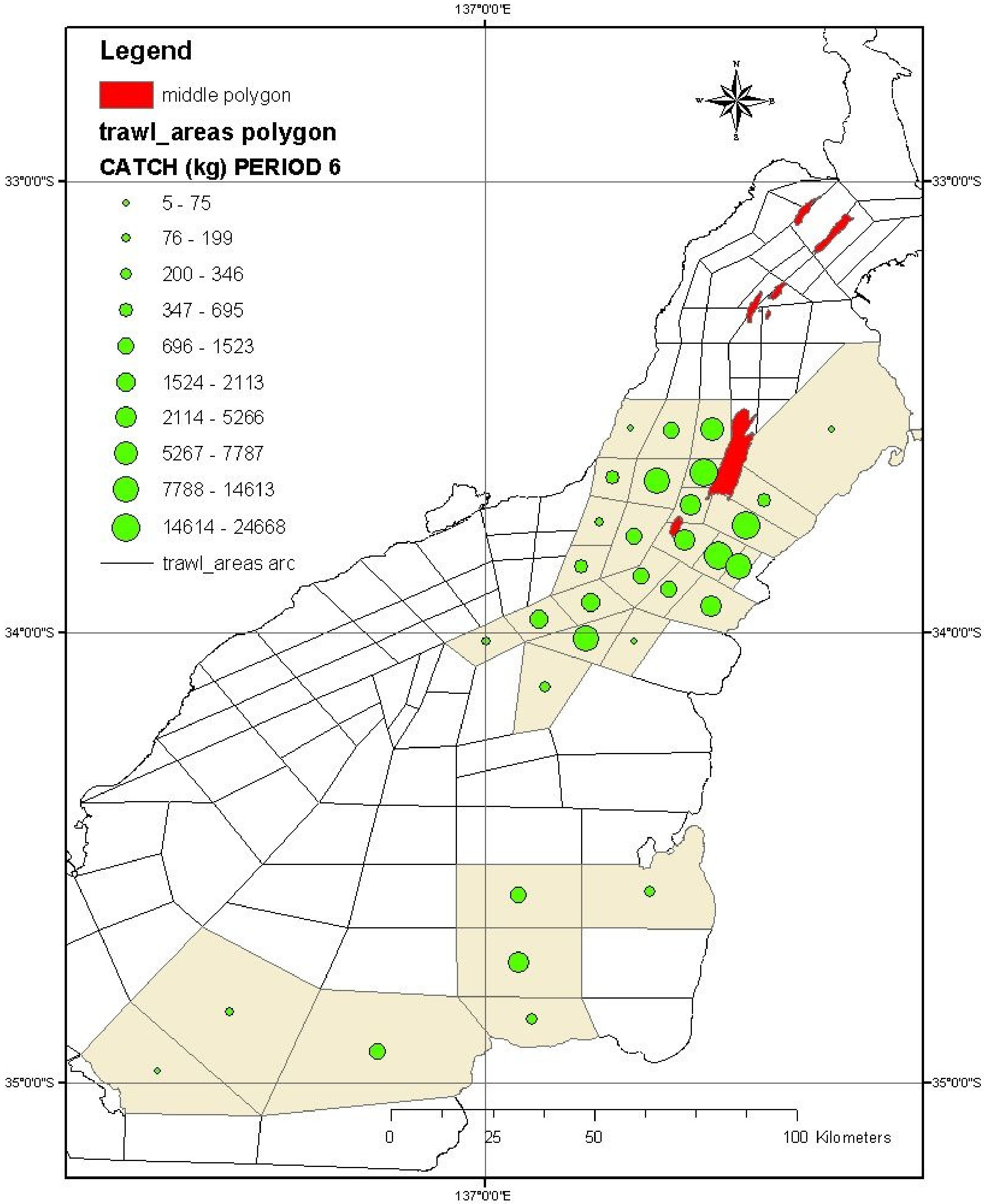


Figure 7.13: Spatial distribution of prawn catch in fishing Period 6, Spencer Gulf, 2001-2002.

7.2.4 Size composition of the prawn catch in 2001/2002

The size composition of the prawn catch is monitored in real time and summarised information is reported to the Prawn FMC and fishing industry following each fishing period. Average prawn size is used as a biological reference point for management. Size limits of prawns captured are necessary to prevent growth over-fishing, which can cause a loss in value of the biomass (and trawl value) by premature harvesting of prawns before the growth maximum is realised (see above). Furthermore, size limits on capture have the potential to maintain population fecundity and are therefore an important mean of ensuring fishery sustainability, providing effort is constrained over the spawning period from November to December when fishing occurs.

Control of the size of prawns captured is undertaken by seasonal and spatial closures. The seasonal closure from December to March allows prawns to grow and spawn and subsequent spatial closures allow the optimisation of bio-value by maximising the growth (and value) increase in the stock.

Owing to the mixture of sizes (cohorts), the use of mean size, based on the number of prawns/standard weight (e.g. 7.2 kg) can provide a misleading and biased picture of the size structure of the stock. Statistically, it is more reliable and less biased for stock assessment to obtain an estimate of the distribution of sizes (length frequency) by sex or by grades with sub-sampling of numbers and weights of the sexes within grades. However, reliable estimation of prawn size distributions requires substantial sampling (manpower) of the commercial catch in different blocks and fishing periods.

The prawn industry grades prawn sizes by the number of whole prawns per lb, an international marketing standard. The most common grades for processing aboard trawlers in Spencer Gulf are U10, 10/15, 16/20, 21/30 and >30 prawns/lb (head on) and a category termed soft/broken (or rejects). The latter comprise prawns which are soft and broken or damaged by blue-swimmer crabs. Larger size prawns have the highest price premium and 95% of prawns captured in Spencer Gulf are mechanically graded with machines whose grading accuracy is tested at sea on a daily basis. Currently, there is a trend to have a larger number of grade categories consisting of U6, U8, U10, 10/15, 16/20, 21/30, 31/40 and >40 prawns/lb which would increase the precision for estimation of size distribution of landed catch.

High quality mechanically-graded prawn size information obtained from commercial fishers allows a large sample size (>90% of fleet) to be obtained from commercial catch data, and is a cost effective method for monitoring catch size composition for biological reference points.

The size composition of catch by commercial grade was monitored on a daily basis over 2001-02. A database was developed to give estimates of daily prawn sizes (grades) for each fishing block. For each day of a fishing period, grade data from all vessels was pooled and the proportions in each grade category were used to estimate the landed catch (kg) in different size categories for each of the six fishing periods in 2001-02. The annual mean size of prawns was estimated using distribution models to fit total catch-grade data for evaluation of size performance indicators. The data fitted to distribution tests were the size categories U10, 10/15,16/20, 21/30 and >30/lb. Allometry functions were used to convert grades to number/kg and to place size class limits on each of the categories. Distribution tests were used to fit the observed sample data to three theoretical distribution functions (Negative Binomial, Neyman Type A and lognormal) to obtain maximum-likelihood estimates of the parameters of the distribution and test for the goodness of fit. The goodness of fit, to the test distribution, is evaluated by the residual deviance (termed deviance), which has an asymptotic chi-squared distribution with the specified degree of freedom (see McCullagh & Nelder, 1989). An interactive Gauss-Newton optimisation method was used to estimate the parameters of the distribution by maximum likelihood using Genstat 5, (see Payne *et al.* 1993).

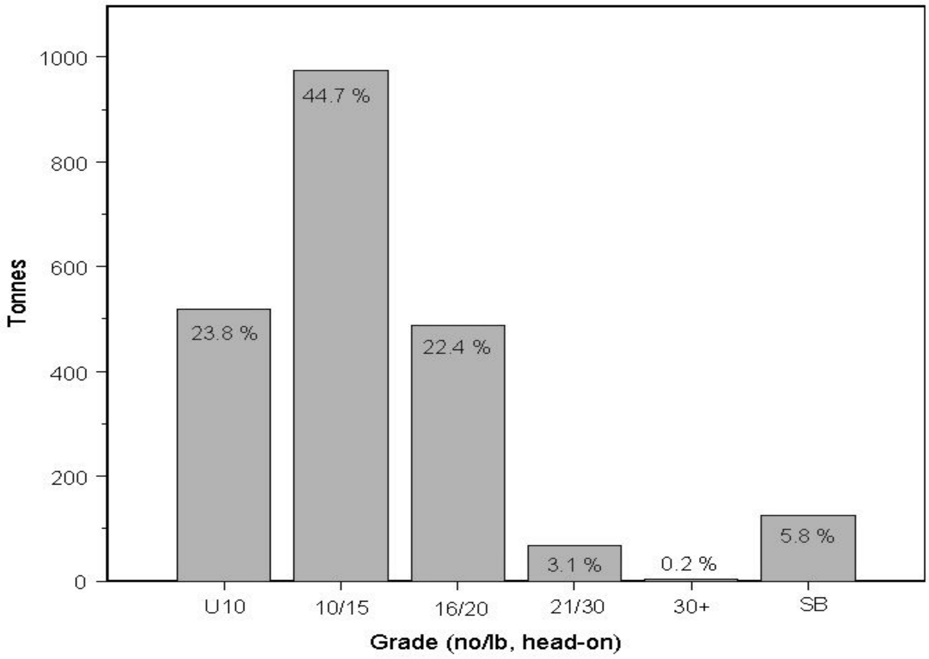


Figure 7.14: The graded size composition of western king prawns landings (tonnes) in Spencer Gulf, 2001-2002.

The mean size of prawns in the 2001-02 catch was larger than the target size specified in the fishery management plan. The catch (tonnes) for the grade categories show that approx. 68.5% (1 495 tonnes) of the catch consisted of the larger size categories with catches of U10 and 10/15 grades being 519.4 and 975.2 tonnes, respectively (Figure 7.14). The amount of small prawns (>20/lb, head on) landed was relatively small (<3.3%), but there was a large amount (125.8 tonnes) of soft and broken prawns in the catch, attributable to damage by blue swimmer crabs (personal observation).

The seasonal size composition of prawns landed and the percentage of soft and broken prawns over 2001-02 are illustrated by a trellis plot (Figure 7.15). For the November/December fishing periods (Periods 1 & 2), 23.8% of landed catch was U10 and 45.8% in the 10/15 category, respectively, with 69.6% of catch being in the combined larger size category.

For March 2002 (Period 3), 29.1% and 42.8% of the catch was in the U10 and 10/15 categories, respectively with over 71.9% of prawns captured in the larger size categories. In April 2002 (Period 4) over 66.9% of prawns landed were in the large size category, which was similar to May 2002 (Period 5), except that the percentage of soft and broken prawns increased from 5.9 to 8.6%. In June 2002 (Period 6) over 70.3% of the catch was in the larger size categories. The amount of small prawns (21/30 and 30+ grades) ranged from 1.8% in June 2003 to 4.2% in March. The results demonstrate a substantial increase in the landed size composition of prawns in 2001-02 compared to the late 1970s (see Section 4.1)

All distribution tests fitted to the size class data was significant ($p<0.01$) with the lognormal having best fit (Table 7.3). The mean weight ranged from 36.91 to 39.91g, i.e., there were 27.1/kg (or 12.3/lb, head on), which is likely to be biased downward.

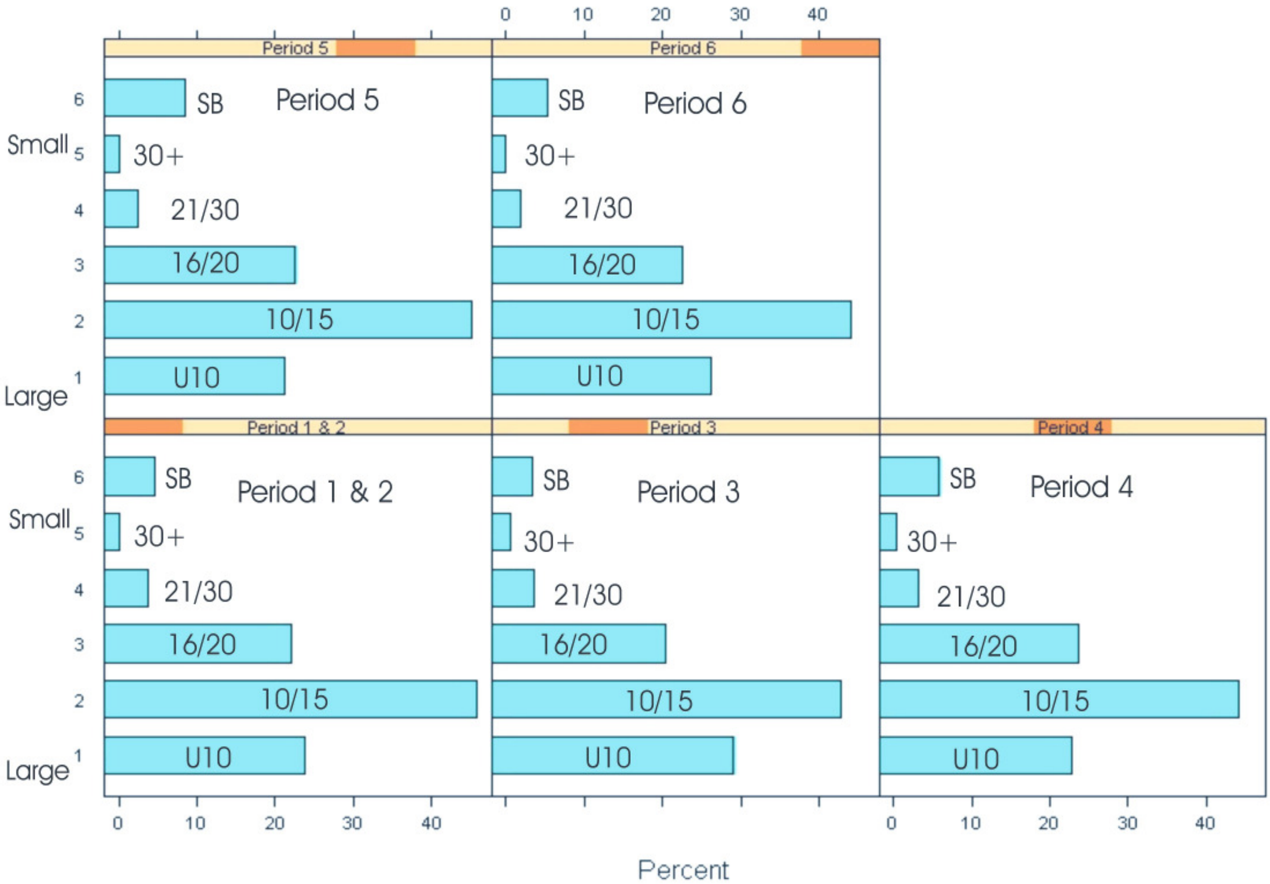


Figure 7.15: The percentage size composition of landed western king prawns over fishing periods 1-6, Spencer Gulf, 2001-2002. Prawn grades are from under 10 prawns/lb (large) to >30 prawns/lb (small).

The size composition of catch was larger than the target in the management plan and demonstrates the benefits of real-time management and strategic harvest strategies (e.g., closures) for optimising the size of prawns captured by the fleet. The concept of a mean size without reference to sex or multimodal size distributions is not a reliable indicator for a biological reference point. Further research is needed to develop better field methods for assessment of population sex and size structure of commercial landings. Grade data based on small size grades (e.g., >30/lb) cannot be used to compare recruitment to grounds (or to the fishery) as different target sizes within the fleet and different harvest strategies (eg. spatial closures & size limits) have occurred over time.

Distribution fits to grade data would be enhanced by having a larger number of grade classes (or limits), as is expected in the future. It is suggested that the biological reference points in the management plan reflect the strategies adopted in different fishing periods and grounds. Prawn size distribution limits have been developed for seasonal and fishing ground targets to ensure the catch is sustainable and to take advantage of premium prices. Most importantly, the amount of small prawns (eg. >30 count) should be kept <2% of the catch. Currently, size group targets are varied during the season to capture price premiums and to optimise population fecundity.

Table 7.3: Distribution fits to commercial size (grade) data, Spencer Gulf, 2001/2002.

Distribution	Size class (g)	Number observed (%)	Number expected (%)	Mean size (g)	Deviance	Df
Negative Binomial	0-15	0	0.93	39.08	6.05	2
	16-21	3	4.54	(± 1.38)		
	22-29	24	16.89			
	30-46	46	52.44	(25.6 /kg		
	47+	27	25.20	or 12/lb)		
Neyman Type A	0-15	0	1.15	38.91	7.59	2
	16-21	3	4.44	(± 1.31)		
	22-29	24	16.05			
	30-46	46	53.66	(25.7/kg		
	47+	27	24.70	or 11.7/lb)		
Lognormal	<15	0	0.36	36.91	2.93	2
	<21	3	4.26	(± 1.04)		
	<29	24	18.98			
	<46	46	50.85	(27.1/kg		
	>46	27	25.55	or 12.3/lb)		

Prior to 2002, prawn grade and size data was obtained on a voluntary basis from a limited number of fishers (15-30) and processing factories on the proviso it would remain confidential. industry supported a case for mandatory completion of grade data to enhance research and management of the fishery. Grade data provided by a number of processors prior to 1984 may be biased towards larger size as at-sea monitoring indicated that the size reported was smaller than that provided by processors. Before the introduction of strict harvesting controls in 1981, there were reports of "dumping" of small prawns (> 30/lb, head on). The size of prawns is monitored daily through grades and "bucket counts" using data obtained from fishers and the harvest strategies developed (e.g., spatial closures) restrict the capture of small prawns.

7.2.5 Conclusions

The work undertaken using the Oracle database and associated SQL report scripts has provided a tool for 'validating' fishers and processor grades from different areas by comparing modelled grades from fishery-independent stock assessment and adaptive monitoring (or spot surveys) survey information supplied by fishers and processors. The size grade data presented above is reliable and small prawns are not under-represented in the grade data from fishers or processors.

The research has resulted in development of a powerful integrated database system which has link to GIS and mathematical statistical modelling software for visualisation and analysis of results. The development of a maximum likelihood procedure for analysis of prawn size grades has provided a valuable statistical tool for monitoring prawn size distributions and approximate means. The data obtained from fisher's commercial catch and effort logbook and grades has proved to be of high quality and the work demonstrates that close collaboration with industry in research and management is needed for effective research and management of a fishery.

7.3 Stock assessment and performance indicators of the Spencer Gulf prawn fishery

7.3.1 Exploitation and depletion estimates based on fishery-dependent catch and effort data.

Background

The estimation of the depletion of stock for the whole of the Gulf population (or the 'global' population) requires data on stock size in closed and open areas. Both catch and effort and survey data is used to estimate stock depletion due to fishing. It is most important to obtain estimates of depletion in the fished population, as 50% depletion over a fishing period across all fishing blocks is indicative of over-exploitation.

The Spencer Gulf fleet has the potential to induce high fishing mortalities as shown for fishing Period 4 in the April 2001 opening of the Wallaroo grounds for 6 days where daily instantaneous fishing mortalities were >0. 2/day (Figure 7.16 & Table 7.4). The fleet targets the highest density spatial aggregations and sequentially fishes down the population. It is important for the fishery to be monitored, on a daily basis, to ensure that fishing effort is constrained to target optimal size prawns with a view to sustainability and optimal economic performance.

Table 7.4: Poisson regression daily instantaneous mortality rates for Period 4 over the Wallaroo trawl grounds, April 2001. Day number 6 was the start date of harvesting and fishing terminated in the region after day number 11.

Day Number	Poisson coefficient	se	t value	Probability level	Antilog of coefficient
6	-0.2091	0.008	-17.35	<0.001	0.811
7	-0.3591	0.012	-28.54	<0.001	0.698
8	-0.5306	0.013	-40.03	<0.0001	0.588
9	-0.5556	0.013	-41.58	<0.001	0.574
10	-0.4617	0.013	-35.59	<0.001	0.630
11	-1.3970	0.018	-77.22	<0.001	0.247

Methods

A data matrix of daily catch rates (kg/h) over each fishing period for each fishing block was extracted from "raw "catch and effort data and used to estimate finite survival in each fishing period. Catch rates were assumed to reflect population trends in fished blocks, as prawn sizes within a fishing block over short time periods (<15 days) remained approximately constant (unpublished data). The finite survival estimate was estimated as final catch rate/initial catch rate over each block over a fishing period. A matrix of depletion estimates was formed for each fishing block over each fishing period and data subjected to a non-parametric bootstrap to estimate mean, standard error and percentiles.

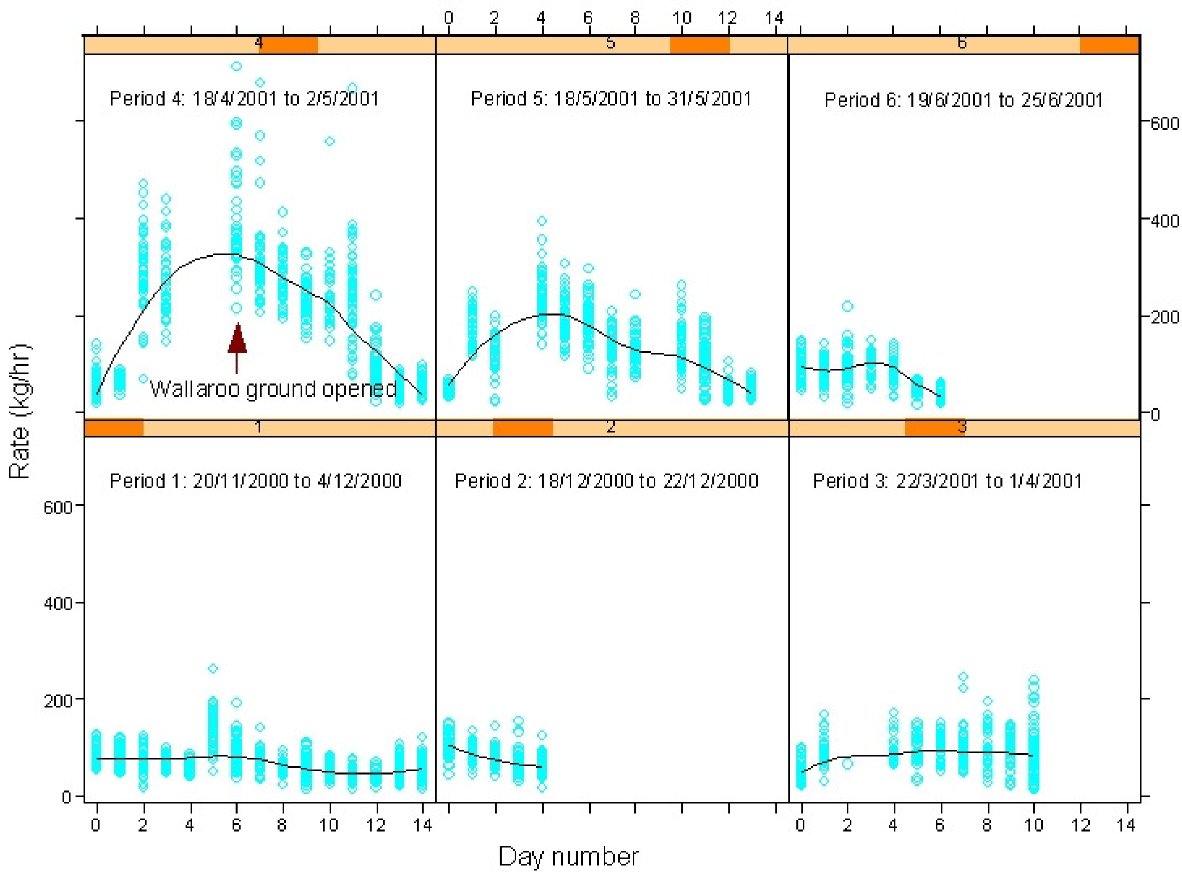


Figure 7.16: western king prawn catch rates over six fishing periods in 2000-2001 showing high fishing mortality rates during the opening of the Wallaroo grounds in April 2001.

Results and conclusions

Mean depletion over fishing periods ranged from 0.24 to 0.38 and the 95% percentile indicated that all depletion rates were less than 0.48 (Table 7.5). The depletion estimates related only to the fished population and were biased upward to estimate the depletion of the total population due the spatial closures (see below).

Table 7.5: Bootstrapped finite mean depletion proportions with standard errors and BCA percentiles over six fishing periods in Spencer Gulf Fishing Blocks in 2001-2002.

Period	Mean	SE	2.5 %	5 %	25 %	50 %	75 %	95 %	97.5 %
1	0.340	0.053	0.231	0.249	0.304	0.340	0.375	0.423	0.438
2	0.306	0.063	0.151	0.179	0.256	0.303	0.343	0.393	0.407
3	0.294	0.078	0.100	0.136	0.231	0.288	0.337	0.399	0.418
4	0.297	0.056	0.181	0.200	0.260	0.298	0.336	0.387	0.402
5	0.382	0.046	0.287	0.304	0.350	0.381	0.412	0.456	0.470
6	0.243	0.045	0.159	0.171	0.214	0.245	0.276	0.320	0.336

For example, in Period 1 (November 2001), the population was reduced by 34%, then in Period 2 (December 2001) the population was further reduced by 30.6%, but fishing was constrained by closures, which prevented depletion in the closed areas. The depletion estimates from Period 4 to 5 are additive, as generally fishing was concentrated in the same areas and results indicate that about 67.9% of the prawn population in the fished area was removed by fishing over 20.5 days. However, large spatial aggregations were reduced by >65% after 6 days of fishing.

7.3.2 Recruits to grounds, February 2002

Background

The fundamental issue for fisheries management is the prevention of recruitment overfishing, i.e. to prevent the spawning stock from being depleted by fishing to a level where it significantly reduces the abundance of recruits. However, for many fisheries, particularly crustacean fisheries, the stock-recruitment relationship (SRR) is unknown. The relationship between the number of spawners and the recruits produced in the fishery and the effects of environmental factors (eg. temperature) on the relationship requires long-term data (>20 years) in order to obtain reliable fit to SRR models. Carrick (1996) showed that recruitment in the Spencer Gulf fishery is influenced by both fishing and environmental variation (e.g., seasonal temperature). A non-linear model of recruits on spawners explained 77.9% of variation in data and was of the exponential form where Recruits = $A + B.R^{Spawners}$ with the following parameters estimates with standard errors in brackets:

R = 0.745 (0.177)

B = -1.84E+12 (3.20E13)

A = 2494.8 (96.1)

When temperature was added in a multiple regression, it resulted in 80.6% of variation in data explained by spawners and temperature, (Carrick 1996). Strong environmental variation which have cyclical trends can mask underlying relationships between stock and recruitment. Hence, a minimum of 20 years of data is required to obtain a SRR relationship over varied scales of spawner abundance, due to the cyclical effects of weather and the need to analyse time series auto-correlations (see Caputi 1988, Hilborn and Walters 1992). Standardised fishery-independent surveys rather than commercial catch and effort data have been used to determine SRR in the Spencer Gulf and the West Coast prawn fisheries owing to problems associated with modelling SRR using fishery-dependent data. Commercial catch and effort data based on CPUE as an index of abundance can provide biased and misleading results owing to many factors, including differences in size composition captured over time due to management restrictions (e.g., closures), problems associated with quantifying real changes in the spatial distribution of abundance, among others.

Methods

A spatial sampling model based on a block structure was used to determine spatial differences in recruitment. Data was subjected to tests of normality and analysed in untransformed and square root transformed mode. The Genstat statistical model used in the analysis consisted of: Block Strata (3), and Treatment Structure POL (Block;1). Block numbers increased from south to north and within each block there were 3 strata consisting of east, middle and west to account for spatial variation across blocks (Figure 7.17). Ideally, it would be better to sample across the blocks (i.e. across environmental gradient) with a minimum of two random shots within each block. However, field experiments on tests of along versus across an environmental gradient resulted in similar mean abundances but proved impractical due to strong tide and sea conditions affecting gear performance (unpublished).

A major objective was to obtain information on spatial size in strata within blocks and sampling across blocks would eliminate the detection of systematic differences in size and abundance over strata. Ideally, sampling must be representative of the dynamic changes in abundance and size distribution which are spatial processes and the adaptation of conventional “Fisherian” sampling plans would eliminate spatial pattern (see Cressie 1993). Quantification and understanding of the abundance changes in time and space are required for management. Hence, trawl survey sampling plans need to consider the spatial processes and require ‘mixed’ objectives which are mainly constrained by variations in abundance and the size composition of prawns (unpublished).

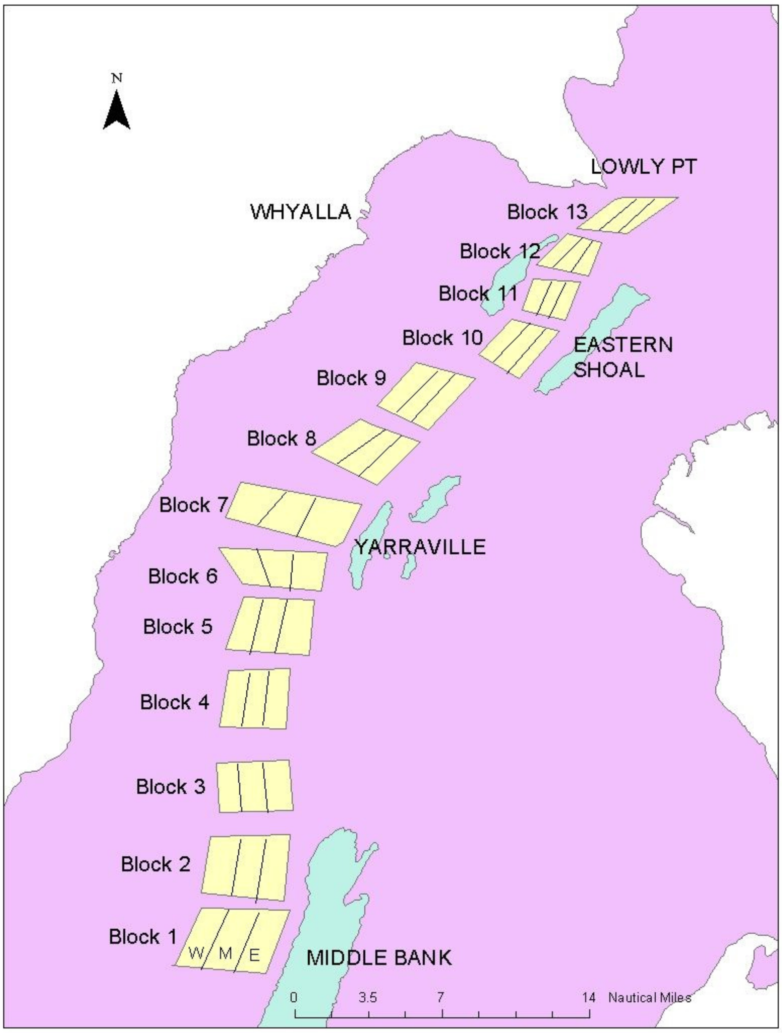


Figure 7.17: Map of 13 blocks used in simple ANOVA and ANCOVA applications.

Spencer Gulf trawl stations were digitised and arcs imported into ArcMap to visualise and compare recruit and spawner densities (z) over location (x and y positions) during different sampling periods. Data from trawl sampling survey in February 2002 was entered in Oracle forms and included log data of catch, trawl location, trawl distance and trawl duration and sample or size frequency of prawn size composition.

Procedures were developed in SQL Plus to raise the numbers of catch over sex, thereby allowing the density (no/nm) of recruits and spawners to be estimated over each sampling site. Here, recruits are defined as prawns <35 mm CL for consistency with the management plan.

Results and conclusions

The analysis of residual patterns and normal tests indicated that a square root transformation of data was required to homogenise variance. The polynomial term was used to determine whether there was a linear trend in recruit density with decreasing latitude. The polynomial term accounted for most of the variance in the data. The results demonstrated that there was a significant ($p<0.001$) linear trend of increasing recruit numbers with decreasing latitude (Table 7.6). Latitude was a significant covariate ($p<0.001$).

Table 7.6: Analysis of variance of recruit mean numbers in Northern Spencer Gulf, February 2002.

Source of variation	Df	SS	MS	F	Probability
Stratum. Strata	2	755.0	377.5	3.49	
Block	12	11356.7	946.4	8.74	<0.001
Linear	1	6019.6	6019.6	55.58	<0.001
Deviations	11	5337.0	485.2	4.48	0.001
Residual	24	2599.2	108.3		
Total	38	14710.8			

The parametric mean recruitment index in February 2002 was 40.311 ± 3.151 for square root transformed data and 2 001.154 (± 257.751) prawns/n mile using untransformed data. The non-parametric bootstrap recruitment mean using 2 000 replications was 40.24 ± 3.11 prawns/n mile with percentiles being 34.1, 35.19, 45.52 and 46.34 for 2.5%, 5.0%, 95% and 97.5% levels (Figure 7.18).

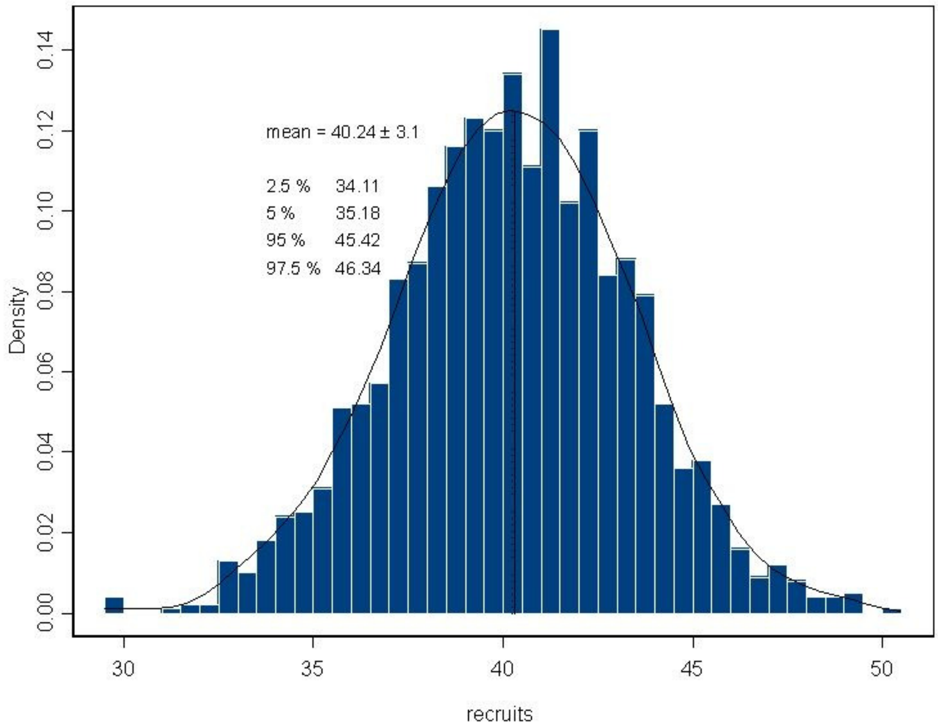


Figure 7.18: Non-parametric bootstrap of mean recruitment index in February 2001.

A Bayesian Markov Chain simulation (Gilks *et al*. 1996) using square root transformed data for 2002 iterations resulted in a mean of 44.94 ± 9.69 recruits/n mile. Hence, the results between the analytical methods appear consistent indicating that the mean recruitment index in February 2002 was slightly larger than the target but significantly lower ($p<0.001$) than for February 2001 (see below).

7.3.3 Evaluation of spatial patterns in recruitment and fishery performance indicators.

Data from the February 2001 stock assessment surveys was used to determine spatial differences in recruitment strength in nine regions (N= 213) using different size groups and indices. The regions were situated from Corny Pt in the south to the northern area of the Gulf, close to the main prawn nurseries. Different size limits (<31 and <35 mm CL) with sexes pooled were used to compare the influence of size limits on recruit numbers/n mile, recruit no/h, and recruit kg/h. Data was unbalanced and subjected to Residual Maximum Likelihood (REML) analysis where region was fixed.

A comparison was made of annual recruitment in 2001 and 2002 using the February trawl survey based on sampling 13 blocks in the northern area (see above). The model structure was based on comparison of recruits in 13 blocks over two years. Using the recruit sizes adopted by Carrick (1996) i.e. males <= 32 and female prawns <= 34 mm CL, the pooled mean number of recruits was 2 140 (± 180) and 37.85 (± 1.83) prawns/n mile using the square root transformation over all regions (Table 7.7). The Northern area (Region 1) had the highest mean density of recruits ($P<0.001$).

Table 7.7: Mean density of recruits (no/nm & square root no/nm) over Region using recruit size categories of <33 and <35 mm CL, respectively for male and female prawns in February 2001.

	All	Region 1 North	Region 3 Wallaro	Region 4 Gutter	Region 5 Cowell 1	Region 6 Cowell 2	Region 7 Cowell 3	Region 8 W-Gutter	Region 9 Corny Pt.	Region 10 S-Gutter	Wald/df	deviance	df	sed
No sites	213	93	25	31	12	12	12	9	12	7				
No/nm	2140	4057	952	522	473	1329	1208	176	1	114	19	3336	203	770
sqrt(No)	38	61	26	21	18	33	30	11	1	10	44	1374	203	6.3

After elimination of areas that historically had consistent zero recruit densities and grouping of the Cowell regions, a re-analysis resulted in an increase in the Wald statistic and reduction in deviance suggesting that the unbalanced design based on proportional sampling provided greater statistical precision when sites with consistent zero recruitment counts were eliminated (Table 7.8). It is noted that 93 sites were used for the northern area, which resulted in a transformed mean of 61.

Table 7.8 Mean density of recruits (no/n mile & square root no/n mile) over Region with reduced sites using recruit size categories of <33 and <35 mm CL, respectively for male and female prawns in February 2001.

	All	Region 1 North	Region 3 Wallaro	Region 4 Gutter	Region 5+6+7 Cowell 1	Wald	deviance	df	sed
No sites	180	93	25	31	36				
No/nm	2451	4057	952	522	1003	35	2977	180	505
sqrt(No/nm)	43	61	26	21	27	64	1236	180	4.1

When different size limits (<31 and <35 mm CL) for pooled sexes were analysed to compare the effects of different size limits on recruits the results showed that size had a large influence on recruit indices (Table 7.9). For pooled regions, the transformed mean for the recruit size <31 mm was 28.51 (± 1.6)/n mile; whereas it was 40.20 (± 1.84) for the <35 mm class. Hence the Northern and Cowell regions 2 & 3 had the highest densities of smaller prawns. Similarly, different size groupings had a large influence on other recruitment indices. The mean number of recruits for Region 1 (northern area) was 9 005/h for the <31 mm CL but 14 612 for the <35 mm size group and the square root transformed means ranged from 46.99 to 62.81/nm.

Table 7.9: Comparison of mean recruit indices over Region in February 2001 using size categories of <31 and <35 mm CL.

	All	Region 1 North	Region 3 Wallaro	Region 4 Gutter	Region 5 Cowell 1	Region 6 Cowell 2	Region 7 Cowell 3	Region 8 W-Gutter	Region 9 Corny Pt.	Region 10 S-Gutter	Wald	deviance	sed
Recruit size < 31mm CL													
No/nm	1352	2623	315	310	296	981	844	90	0.1	474	102	5252	626
sqrt(No/nm)	29	47	14	15	13	28	22	7	0	6	247	1360	6
No/h	4602	9005	1082	1031	968	3027	2694	269	0	142	109	3744	2094
kg/nm	14	28	4	4	3	9	8	1	0	1	124	1357	6
Kg/h	49	95	14	12	10	27	26	3	0	2	137	1838	20
Recruit size < 35mm CL													
No/nm	2336	4340	1282	606	545	1432	1378	216	1	142	793	3348	794
sqrt(No/nm)	40	63	31	23	20	34	33	13	1	11	6	1377	6
No/h	7838	14612	4473	2005	1777	4453	4415	649	3	426	178	3822	2534
kg/nm	32	59	22	9	8	17	18	4	4	0	2	1576	10
Kg/h	108	196	77	30	25	53	58	11	0	8	32	2036	32

The results of ANOVA of recruit strength in 2001 and 2002 showed that recruitment was significantly lower in 2002 than in 2001, with large differences between blocks in the spatial distribution of recruits (Figure 7.19). Recruitment in 2001 tended to decrease from south to north whereas it increased in 2002, with many more recruits in blocks 1-4 in 2001 than in 2002.

The year effect was high (i.e. the untransformed mean was 4 202 recruits/n mile in 2001 and 2 005/n mile in 2002). For the transformed data, the mean in 2001 was 61.6 recruits/n mile; whereas in 2002, it was 40.3 with a sed of 4.6. Examination of residual patterns and norm tests showed that the square root transformation homogenised variance.

There were large differences in the spatial distribution of recruits over blocks between 2001 and 2002. Recruitment in 2001 tended to decrease from south to north whereas in 2002, it increased. The numbers of recruits in blocks 1 to 4 in 2001 were substantially larger than in 2002. For the transformed data, the mean square error for year was 8 793.4 and the residual mean square was 413.1. The results show that the spatial distribution in abundance of recruits in 2001 was higher that 2002.

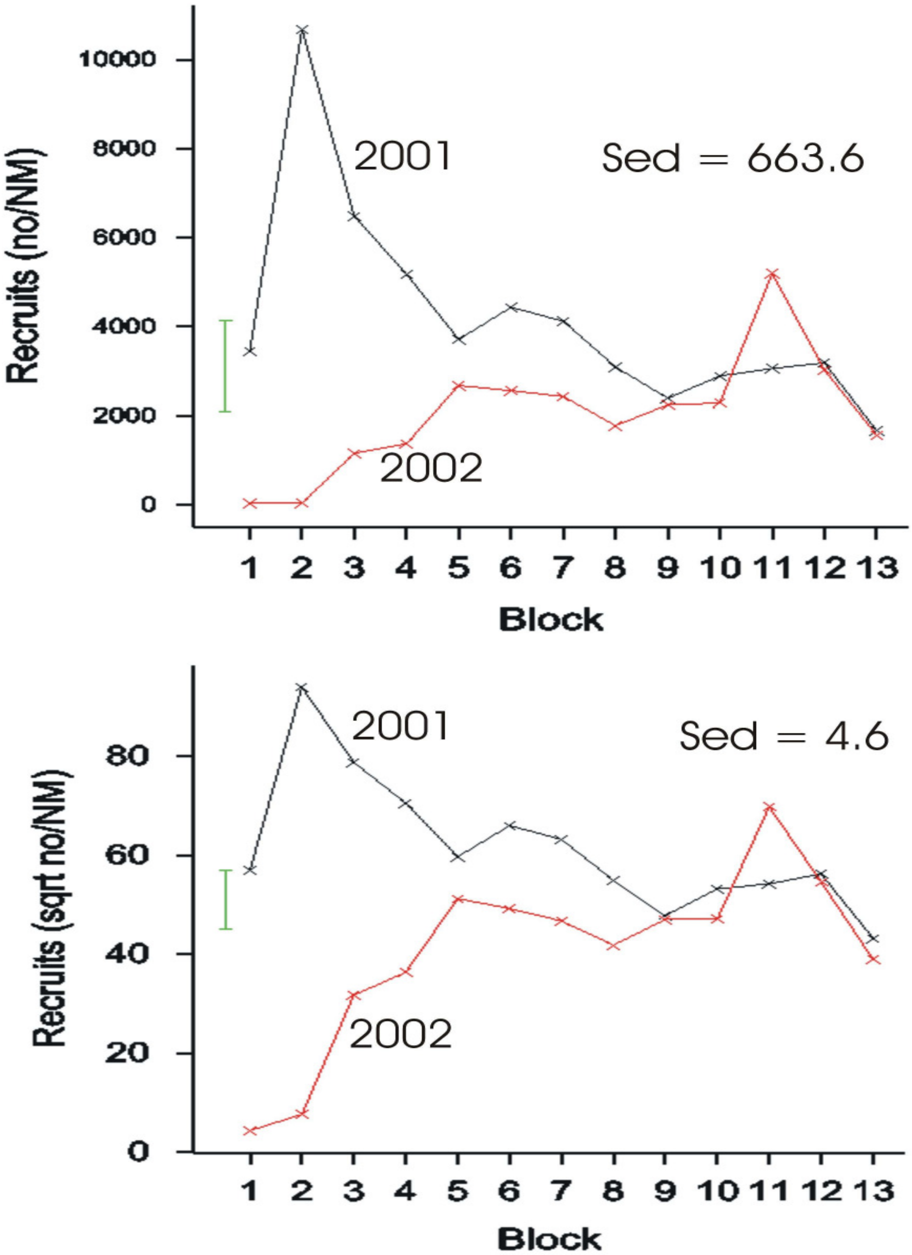


Figure 7.19: Comparison of prawn recruitment densities in 2001 and 2002 over 13 blocks in Spencer Gulf. The error bar is the standard error of difference (sed) between means over Year x Block; whereas the sed values of 663.6 and 4.6 are for the Year effect

The results indicated that there was high statistical power (>0.98) in detection of difference (at alpha = 0.05) in means between the two years using the 13 block-sampling plan. This was due to the relatively low (and similar) standard deviations in recruits between years (approximately 20.57 v 19.73) and the large difference between means (52.9%). The "effect size" and standard deviations are most important as retrospective analysis of the power.

Only 20 replicates would allow a significant difference in annual means to be detected at the 95% level for 1987 versus 2001. In contrast, for 1987 versus 1988 means, for power of 0.8, >90 replicates were needed to detect a 30% difference in means at $\alpha = 0.05$.

7.3.4 Biomass density comparisons

The biomass density (kg/nm) from the February trawl stock assessments surveys of the prawn stock was compared from 1987 to 2002. Four main Area comparisons were: the northern area, Wallaroo, the Gutter and Cowell, with 109 sites sampled over Year (7 levels, 1987, 1988 & 1998-2002) using consistent stations. Biomass density provides an indicator of stock size when sampling covers main areas. Data was unbalanced and subjected to a 1-way ANOVA and REML to compare differences in annual mean biomass in 1987,1988, and 1998-2002. Residual plots indicated that data was normal and retrospective tests were undertaken of the statistical power, as done in 1988, to increase precision and avoid type 1 error. The detection of a 30% difference in means at power = 0.8 for $\alpha = 0.05$ was planned in 1988 with view to increase sample size >200.

Annual comparisons of biomass density means (kg/h) showed large inter-annual differences (Figure 7.20). The year 1987 had the lowest mean biomass and 1998 and 2001 the highest, which was reflected in commercial catch rates and production. In the future, the biomass density should not be allowed to fall to the 1987 "limit threshold" level of 103.32 kg/h, indicative of a stock in decline. The 2002 biomass density did not differ significantly from that of 1988 (see Appendix 8a,b).

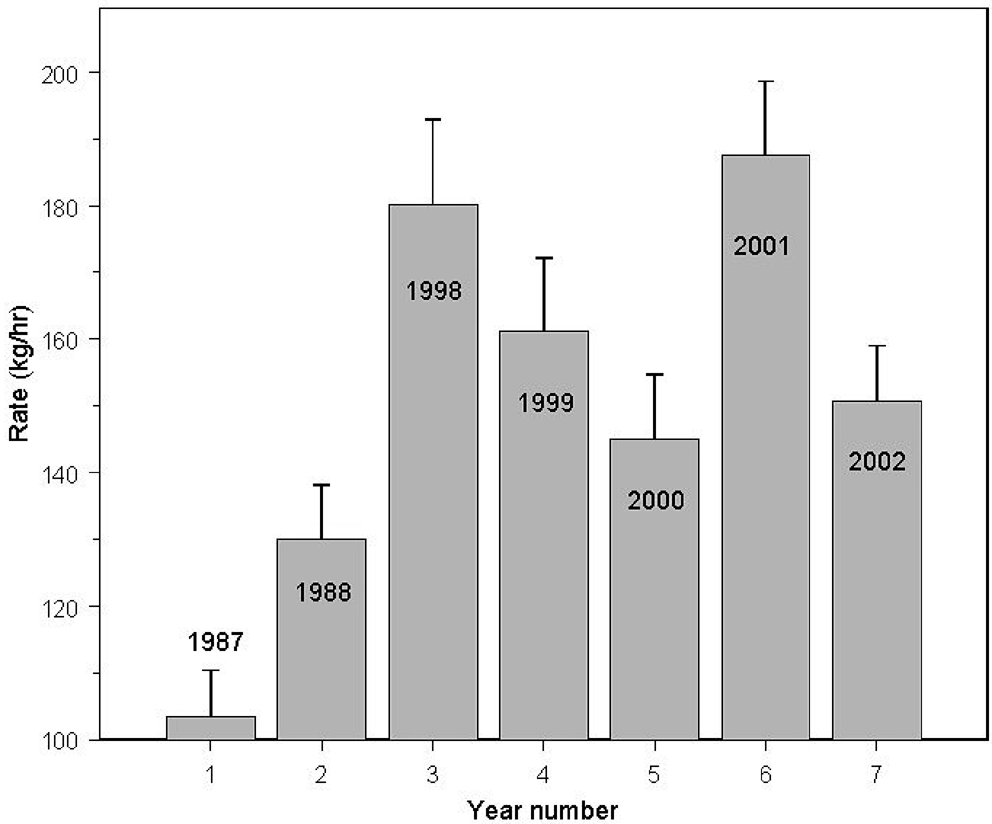


Figure 7.20: Annual comparisons of western king prawn biomass density (kg/hour) using 109 trawl stations, Spencer Gulf.

The minimum detectable difference in means (delta) between 1987 and 1988 using 109 stations (for power = 0.8 and alpha = 0.05) was 30.03 kg/h resulting in a mean of 133.40 to detect about 29.07%. difference. When the number of stations is increased to 220, the delta value declined to 21.14 or 20.46%. In comparing 1987 and 2002 using the same power and alpha levels for 109 stations, the delta value was 30.43 or 29.5% and when the number of sites is increased to 220, the minimum detectable difference was about 20.5%. The sample size required to detect a significant difference in means between 1987 and 2002 was 45 but this could only detect a 43.8% difference in the means. For an alpha level of 0.01, for power = 0.8 the minimum number of stations required to detect a difference was 67 and if alpha was set to 0.005 the minimum number of sites for detection of difference was 77. The number of sites required to detect a significant difference means between 1988 and 2002 for power = 0.8 and alpha = 0.05 was 268, however, if power is reduced to 0.7 only 211 sites are required to detect a difference in means at the 95% confidence level. Residual distributions indicated that both untransformed and square root transformed data was normal. Scheffe's multiple comparison tests showed that the lowest biomass density over all years was 1987 and the highest were 2001 and 1998.

Comparisons of regional or Area (4 levels) differences between years showed large variation in biomass density over different regions for Year (Figure 7.21). The biomass density in February 2002 for the Northern region was significantly ($p<0.005$) less than 1998-2001, but not significantly different from those of 1987 and 1988 (Appendix 8c). The sample size would need to be increased from 59 to 86 to detect a statistical difference between 1987 and 2002 for a power value of 0.8 with alpha = 0.05. However, for the square root transformation a sample size of 64 is needed to detect a difference at same power and alpha values.

The results indicate that there was no statistical difference in the biomass density between 1998 and 2002 for the Northern region and >1 300 replicates (trawl shots) would be needed to detect change between the two years. Background research has shown that at least 90 trawl shots (replicates) are required to enable adequate statistical comparison of biomass density with the baseline year (1987).

Wallaroo (Region 2) is the main fishing ground in Spencer Gulf, and from 1987, harvest strategies were developed for "re-building" that stock. The highest mean biomass density occurred in 2002. What is most apparent is that in 1987 and 1988 the standard deviations were substantially lower than in all years used in the comparison (e.g., 21.4 in 1987 versus 133.79 in 2002). Untransformed data for test of the Year effect was normal and the mean biomass increased from 31.24 in 1987 to 204.5 kg/h in 2002. Scheffe's multiple comparison test showed that the mean in 1987 and 1988 was significantly lower than in 2002, but there were significant biomass differences between 1998 and 2002 (Appendix 8d). The power to detect a significant difference between 1987 and 2002 for n = 15 was 0.95. However, the detection of a significant difference between Wallaroo biomass means between 1998 and 2002 (at power 0.8 for alpha = 0.05) required a sample size of 26, which is consistent with a recent increase in sampling stations (N = 32) to increase precision based on contrast with 1998. The mean biomass for Region 3 (Gutter) in 2002 was lower, but not significantly, than the baseline (1987) and only in 2001 was biomass significantly higher than in 2002 (Appendix 8e).

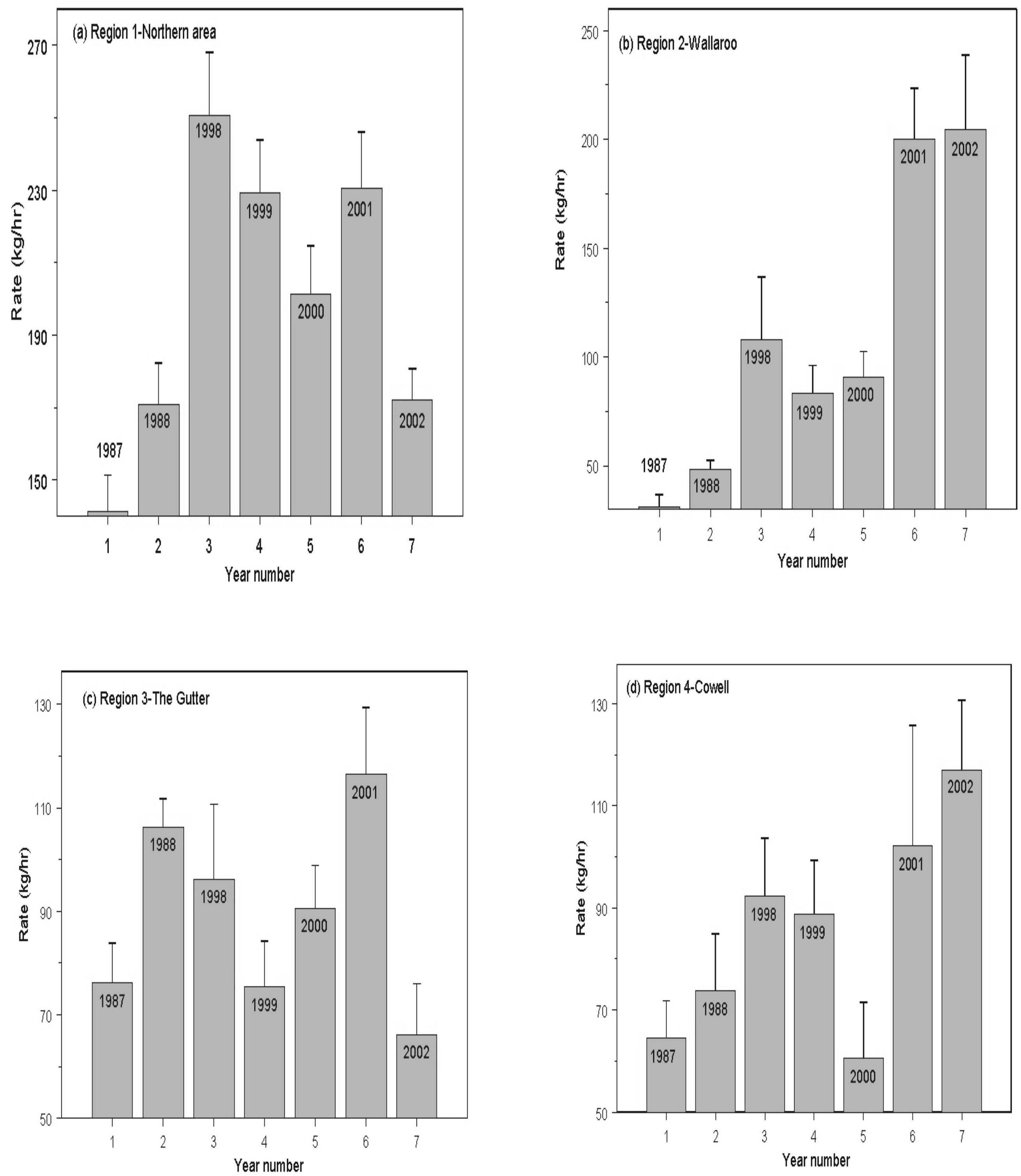


Figure 7.21: Comparison of annual biomass density (kg/h) over four Regions in Spencer Gulf from February trawl surveys.

The project resulted in the development of a database and report tools for the assessment of recruits, egg production, large spawners and biomass density over different regions of the Gulf. Owing to cost constraints, there is a need to rationalise the sampling plan and size frequency samples collected from the surveys. The analysis of statistical "power" using unbalanced multi-factorial sampling plans is not trivial and is being addressed.

The number of replicates required to detect a statistical difference at alpha = 0.05 and power = 0.8 between 1987 (base year) are different for the responses (biomass and recruit densities) and a decision framework needs to be developed for rationalisation as the spatial distribution of recruits is largely different to that of spawners. One must determine the priority response to enable trawl sampling to be optimised. The sampling plans currently developed had mixed objectives including the determination of prawn size composition for spatial closures. If recruitment is the main response then historical sampling sites which have consistently had negligible spawner number (and low variances) should be eliminated in the sampling plan, with greater emphasis placed on recruit areas which have high densities and variances. Most importantly, an acceptable level of precision needs to be agreed upon and risk frameworks implemented for management.

Carrick and Correll (1991 unpublished) tested trawling across an environmental gradient to reduce variance and minimise sampling costs. However, this method posed problems including a loss of information on the fine-scale size distribution which was needed for the delineation of closure lines. The FRDC project resulted in the development of database, mapping and statistical modelling tools for a more extended analysis and re-appraisal of the cost benefits of sampling across strata, as opposed to along an environmental gradient.

7.3.5 Depletion and exploitation based on fishery-independent data

Fishery-independent survey sampling provides a reliable method to assess the impact of fishing (depletion) on the prawn population as both open and closed areas are sampled. However, sampling can be biased if insufficient sites (replicates) are taken, especially over areas that have been fished. The reduction of stock over the April to November period provides a less biased estimate of the reduction in spawning biomass due to fishing. However, a more reliable method is to subject data to a detailed cohort analysis, requiring a minimum of 288 simulations over each period.

Survey data from April and November 2002 was used to obtain estimates of stock depletion. The surveys took place in the Northern area, Wallaroo region and the Gutter with 143 sites used in April and 144 in November. For each period over each site the numbers of prawns were estimated using catch/mean size of prawns and numbers standardised to numbers/30 minute trawl. The mean number of prawns was estimated (pooled sites, N= 144) over each period and data adjusted for catchability (q) differences between periods and for various rates of M over the six month period (viz 0.07-0.04 per month, Carrick 1996). This method allowed estimates of the depletion using survey data and CPUE; size data from fishing operations in April and November was combined with the survey data to obtain another estimate of depletion by the fleet. Similarly, the effect of natural mortality (M) and catchability (q) was removed in the analysis. Data on fishing depletion consisting of results obtained from 16 simulations to remove bias due to natural mortality and catchability was subjected to a non-parametric bootstrap. Data on the numbers of prawns/h from surveys and commercial catch and effort (kg/h) was pooled for April and November, and the depletion adjusted for natural mortality differences over the two periods. Similarly, data was subjected to a nonparametric bootstrap to estimate mean depletion.

Using the survey results, the mean number of prawns was 4 026.56 ± 61.85/h in April and 1 752.88 ± 78.64 /h in November. The bootstrap depletion estimate was 0.416 ± 0.08 (Figure 7.22). Using the combined survey and logbook data, the mean number of prawns was 6 444 ± 363.1 in April 2002 and 2 652 ± 158.1 in November. Note the reduction in variance in the population following fishing. The bootstrapped mean for the pooled data set (survey and fishing) from April to November was 0.447 ± 0.007 (Figure 7.23).

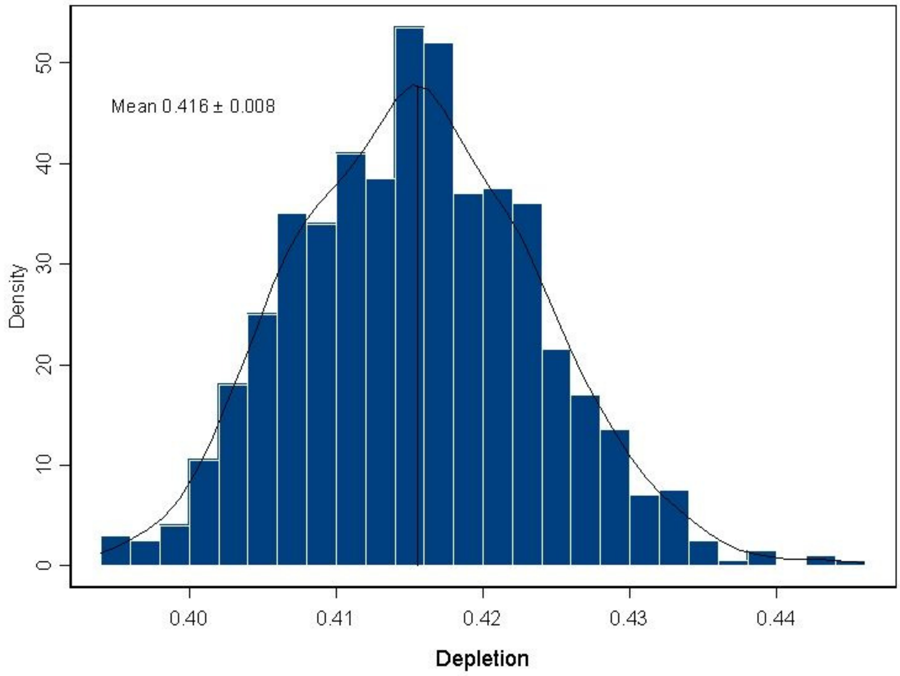


Figure 7.22: Non-parametric bootstrap of mean depletion of spawning biomass from April to November 2002 using fishery-independent trawl survey data.

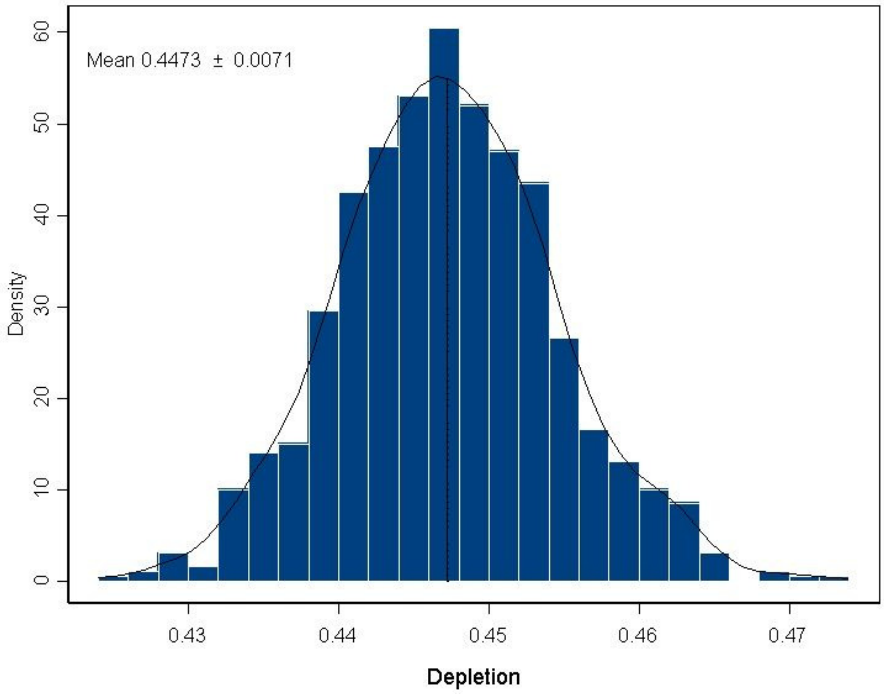


Figure 7.23: Non-parametric bootstrap of mean depletion of spawning biomass from April to November 2002 using both trawl survey and commercial catch and effort data.

7.3.6 Performance indicators in the Spencer Gulf prawn fishery

A summary of the biological performance indicators is outlined below. The key indicators are effort (number of days trawled), spawning biomass, recruitment index and average prawn size (Table 7.10).

Table 7.10: Summary of biological performance indicators for the Spencer Gulf prawn fishery, 2001/2002

	Reference points		
Performance indicator	**Target**	**Limit**	**2001/2002 season**
Effort (effective days)	70-80	85	55.5 days Effective = 76.59
Spawning biomass (% virgin biomass)	50	40	58.4 % (depletion 0.416-survey) 55.27 % (depletion) 0.4473 - survey & logbook)
Recruitment index (square root recruits per nm)	40	35	40.31 ± 3.15a* 40.24 ± 3.15b 44.90 ± 9.69c
Prawns per kilogram	<40	40 or more	27.9/kg (12.7/lb)

* Recruitment indexes a, b, c refer to ANOVA, non-parametric bootstrap and Bayesian MC estimates, respectively.

The nominal trawl effort in 2001-02 was 55.5 days but the effective effort exerted was equivalent to 76.59 fishing days by the fleet. Hence, the effort exerted in the fishery was marginally lower than 80 effective effort days set in the management plan.

Two methods were used to estimate the depletion of the “virgin” spawning biomass and the percentage of stock left for spawning. The target reference point is 50% and approximately 55.3-58.4% were left to spawn.

Three methods were used to estimate the recruitment index, which is based on the square root transformation of the numbers of prawns/n mile. The recruitment index was estimated at 40.3-44.9. However, the least biased estimate is 40.3, which is marginally higher than the target reference point of 40.

Over 65% of the landed catch was <16 prawns/lb (head-on) and the average size estimated by maximum likelihood using modelled distributions was 27.9 prawns/kg (or 12.7/lb), which was larger than the upper limit (40/kg) of the target size in the management plan.

A fishery-independent trawl survey conducted in February 2003 indicated that the recruitment index declined to near 35 (see Section 7.5). Information was reported to industry and the FMC in March 2003 with immediate steps taken to develop harvest strategies designed to reduce trawl effort and exploitation, (see below).

7.3.7 Conclusions

The results demonstrate that the joint use of fishery-dependent catch and effort information and fishery-independent data allow important fishery parameters to be estimated which are of significance to assessment of fishery sustainability and for management.

7.4 Spatial changes in prawn production and appraisal of the benefits of adaptive harvest strategies and spatial closures in Spencer Gulf.

7.4.1 Background

A summary of the main changes in the spatial distribution of prawn landings in Spencer Gulf from 1977-78 to 2001-02 provides support for the benefits of adaptive harvest strategies for stock sustainability and increase in fishery profitability. In 1979, it was well known that the Spencer Gulf prawn catch had the lowest quality of king prawns in Australia, mainly attributable to the small size landed and the extended use of refrigerated brine. As from 1981, harvesting strategies were implemented using “trial and error’ evaluation and adaptive management in collaboration with industry with view to improve the research and management of the fishery. A suite of information sources were used to develop and evaluate harvest strategies including: catch and effort data, information on prawn grades and monitoring of prawn size captured at sea, movement and growth, prawn abundance and spatial size composition from fishery-independent trawl surveys and results from harvest model simulations. A number of controversial closures and harvest sequences were implemented from 1977-78 to 2001-2002, namely:

- Closure of historically important grounds in the northern sector of the gulf (e.g., Lowly Channel, Yarraville Basin and Eastern Shoal) and sections of the Cowell grounds.
- Introduction of moon and daylight trawl closures.
- Elimination of trawling in January and February and from July to October.
- Delay in harvesting the northern and Wallaroo grounds.
- Closure of sections of Wallaroo grounds.

Research has resulted in a reduction in nominal trawl effort and growth overfishing with the fleet directed to areas of larger prawns. Furthermore, strategies have involved delaying harvesting and reducing exploitation on spawning prawns over the October-March period, the prime objective being to ensure the sustainability of the fishery.

7.4.2 Logbook systems and mapping

Prior to 1985, logbook data was based on a grid system consisting of 6 x 6 nautical miles in latitude and latitude. The grid system was changed following information gained from field studies on the size composition of prawns during fishing operations with industry and research recommending the implementation of an improved system, more spatially representative of grounds and prawn size composition. A visual basic script obtained from ESRI was used with ArcMap software to construct the old grid polygon layout for the visualisation of catch and effort data (Figure 7.24). Data from annual grid catches was mapped in 2D using ArcMap with conversion to vector and raster formats for 3D visualisation.

In the 1977-78 financial year, the landed catch was 1 680 tonnes for 38 948 trawl hours with an annual rate of 42.2 kg/h. The spatial distribution of landed catch (tonnes) is represented by graduated symbols (green) and by graduated colour ramp. Larger catches have more intense red colour (Figure 7.25). In 1977-78 the largest landings were from the northern part of the Gulf near Whyalla (C077, C275) and from the Cowell area (grids C868 and C869). Information from processor size grades and survey sampling indicated that the bulk of the catch consisted of small prawns in 1977-78, which was attributable to the spatial distribution of fishing operations, (see below).

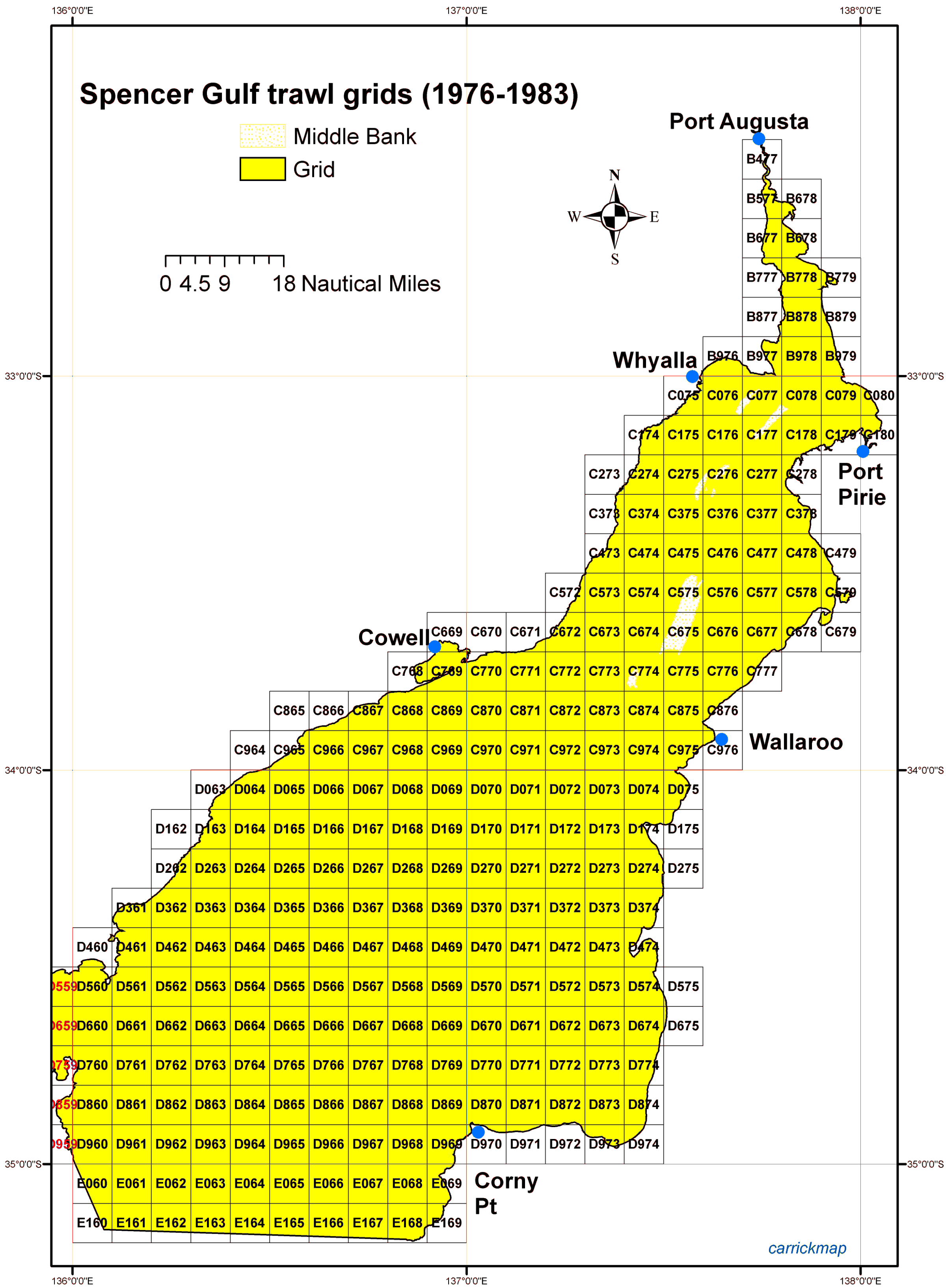


Figure 7.24: Prawn catch and effort daily logbook grid system used prior to 1985

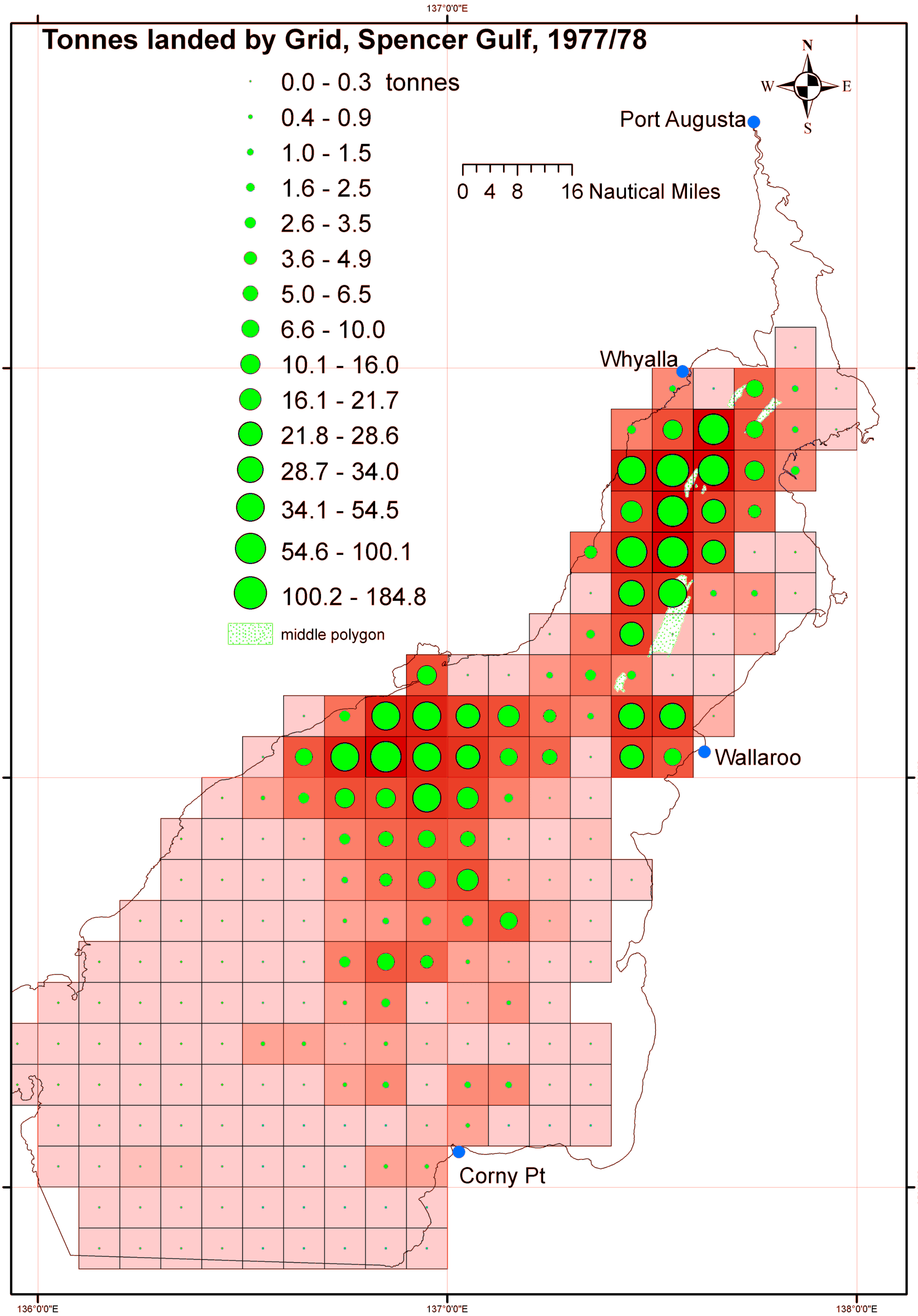


Figure 7.25: Spencer Gulf catch (tonnes) overfishing grids in 1977-1978.

In the 1978-79 financial year, the landed catch was 1 987 tonnes for 45 786 trawl hours with an annual rate of 43.4 kg/h. The largest landings were from the Cowell region and the northern section of the Gulf (Figure 7.26). Prawn catches from the Wallaroo (C775, C875 and C874), Middle Bank (C674), Gutter (C971 and C972) and Corny Pt (D570, D569 and D670) areas in 1977-78 and 1978-79 were relatively small compared to subsequent years (cf. 1998-99 and 2001-02).

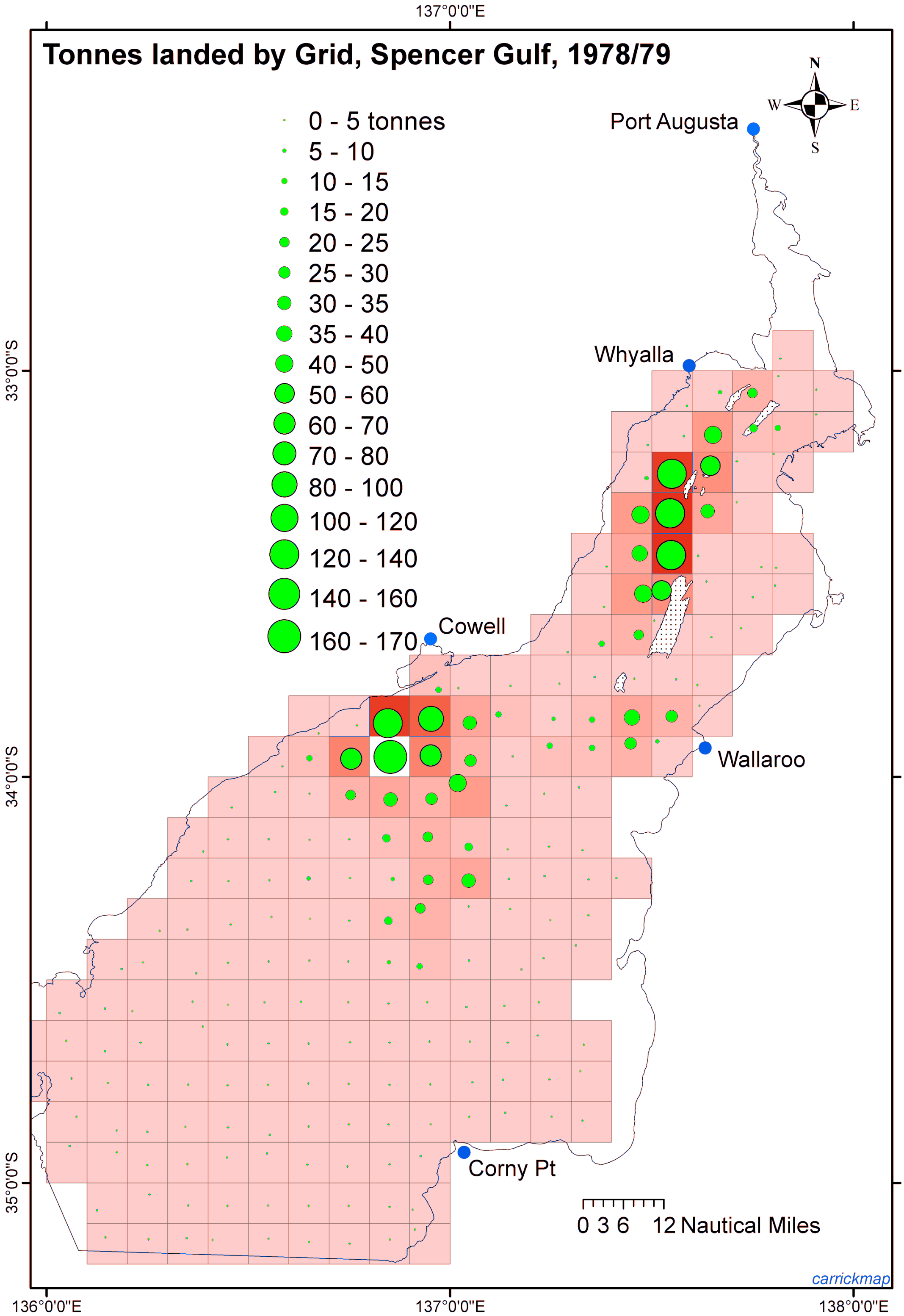


Figure 7.26: Spencer Gulf catch (tonnes) overfishing grids in 1978-79.

The spatial distribution of landings for 1978-79, when interpolated and viewed in 3D (Figure 7.27), shows a large catch from the Cowell area and relatively low catch levels from the Wallaroo and Middle Bank areas compared to subsequent years (see below).

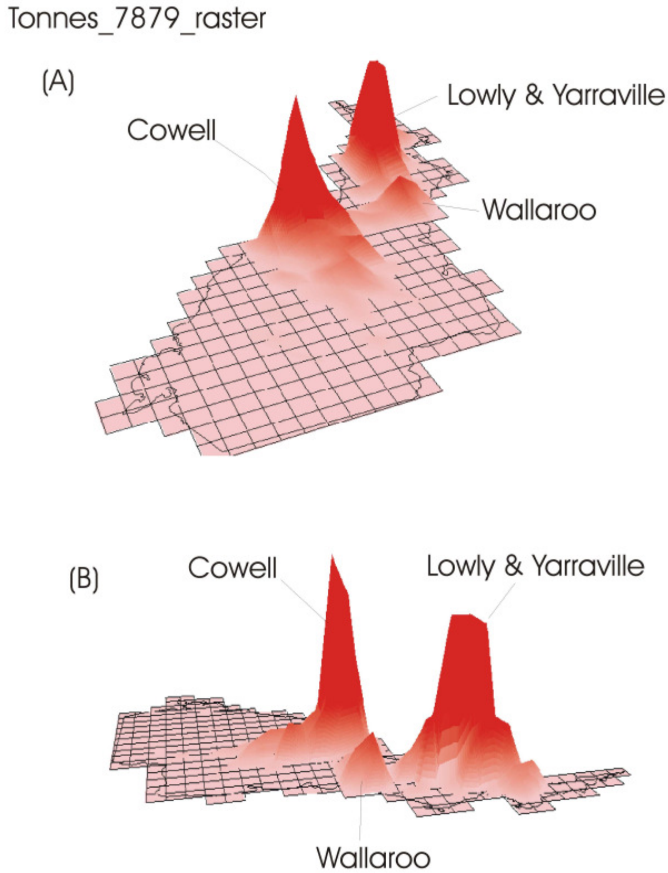


Figure 7.27: A 3D view of spatial catch (tonnes) in Spencer Gulf, 1978-79.

In June 1980, a large section of the Cowell region was experimentally closed to trawling as fishery-independent trawl sampling and observations of fishing operations showed that >60% of the catch from April to June consisted of small prawns (26/30 and >30 prawns/lb, head on). Prawns were tagged in the area over 1980-81 using coloured anchor tags to determine prawn movement within and outside the Cowell area, with recaptures obtained by survey sampling within the closed area and by commercial operations in the region open to fishing. The objective of the closure was to determine whether the prawns at Cowell moved or “fed’ the Wallaroo and Gutter areas, thereby resulting in an increase in production from those grounds.

The Cowell closure proved successful as landings and catch rates largely increased in the Wallaroo region, with verification of a movement pathway from Cowell to Wallaroo, Carrick (1982). In 1980-81, fishing was temporally and spatially restricted in the Lowly and Yarraville areas as results from fishery-independent trawl surveys showed that prawns were mainly of sub-optimal size from January to June. Closure descriptions for 1980-1982 are illustrated in Carrick (1982). Landings in 1980-81 were 1 918 tonnes for 40 363 hours trawling with an annual catch rate of 47.5 kg/h.

Figure 7.28 illustrates prawn landings by fishing grids with largest landings from the Stones (C475), South Yarraville (C375) and Wallaroo (C874 & C875) grounds. Landings from the Middle Bank region (C674) were relatively low compared to subsequent years.

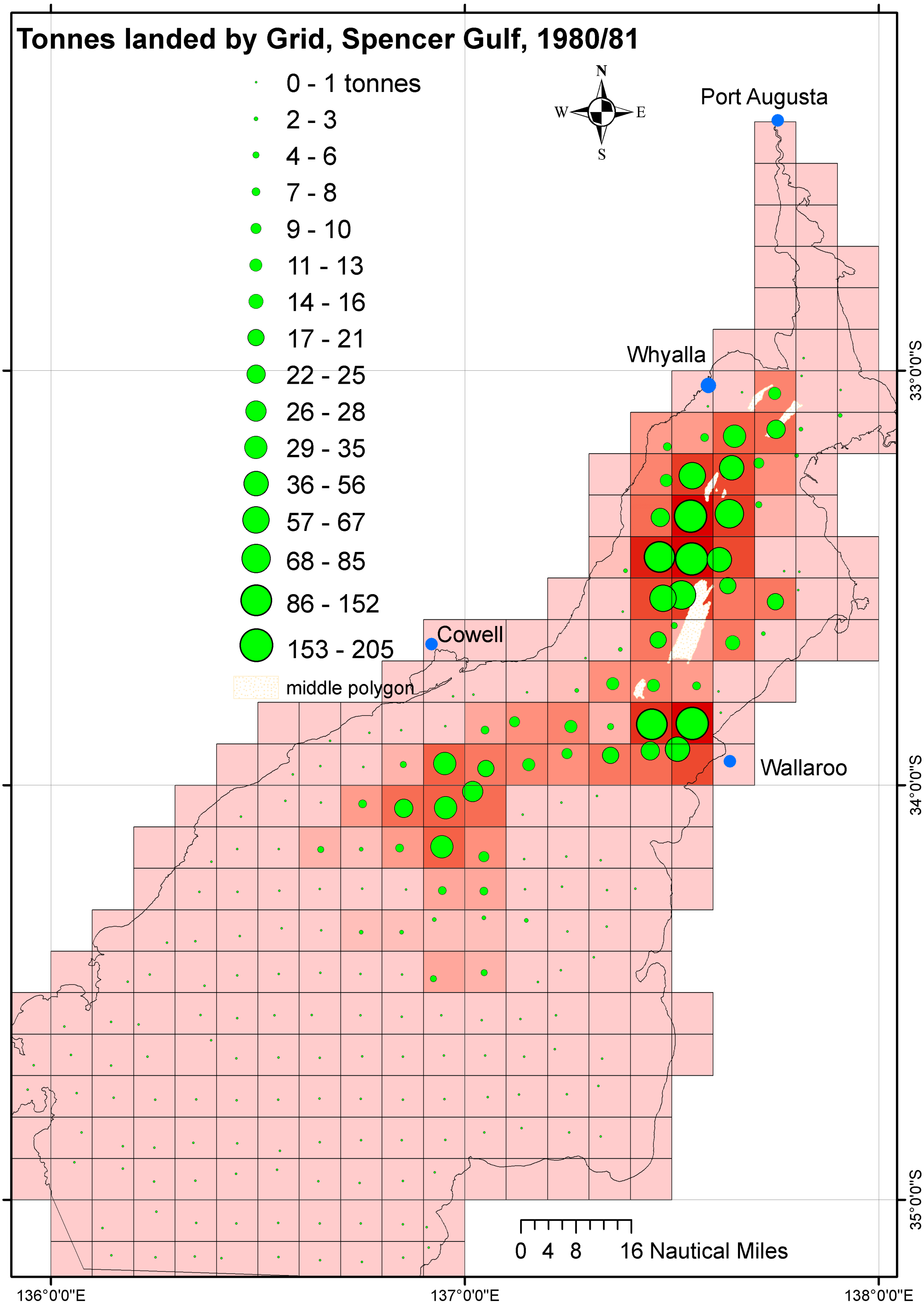


Figure 7.28: Prawn landings (tonnes) by grid in Spencer Gulf, 1980-81.

The distribution of catch for 1980-81 viewed in 3D is illustrated in Figure 7.29. It was hypothesized that prawns from the northern area would move to the Middle Bank and Wallaroo areas and that delay in fishing would result in a trawl value ($/h) increase of the population as prawns grew to a larger and more valued size. Subsequently, studies on the spatial distribution, temporal spatial profiles, seasonal growth patterns and mortalities showed that reducing the catch of smaller prawns in the northern section of the Gulf over strategic periods resulted in a large biomass and value increase in landings when prawns were allowed to grow over the fastest growth periods (February-April).

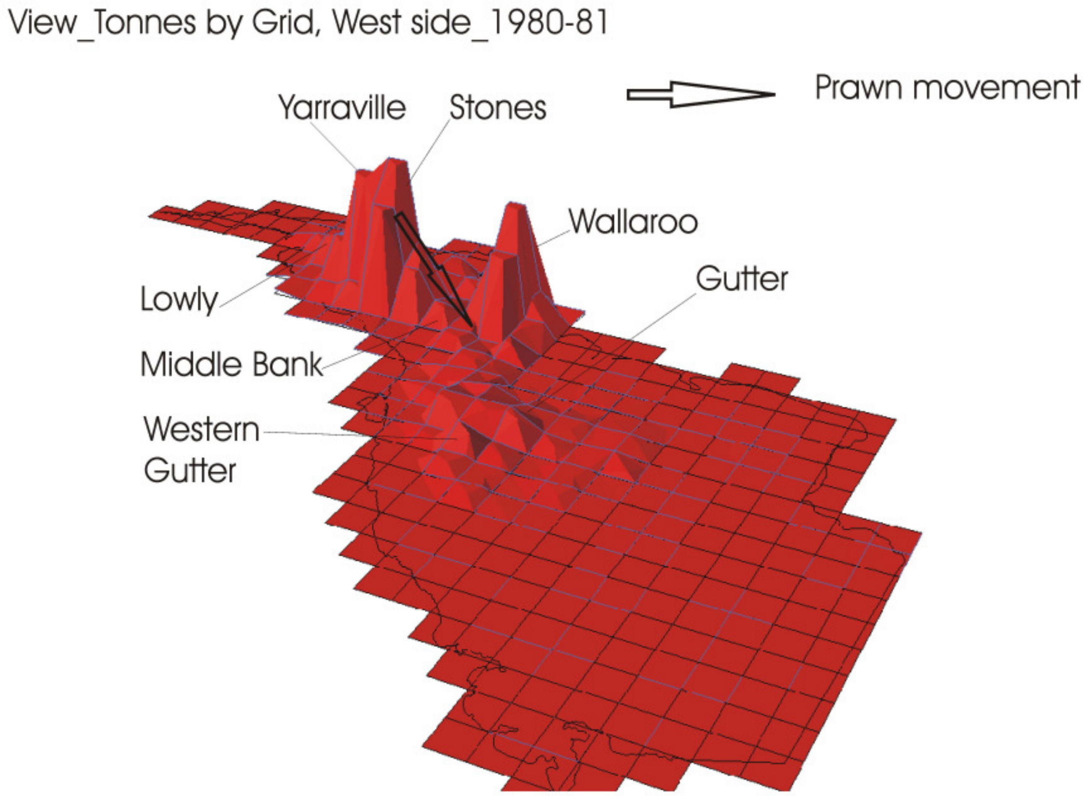


Figure 7.29: Spatial landings in Spencer Gulf viewed in 3D, 1980-81.

The From 1985, daily catch and effort data locations were based on a block system consisting of asymmetrical polygons, (see above). Prawn landings in 1997-98 were 2 300 tonnes for 23 000 hours, with an annual rate of 103.2 kg/h. In 1997-98, the majority of prawn landings were taken from the Wallaroo (Blocks 43 & 44), Middle Bank (blocks 31 & 36), Corny Pt (block 87) and the Gutter (blocks 51 & 52; Figure 7.30).

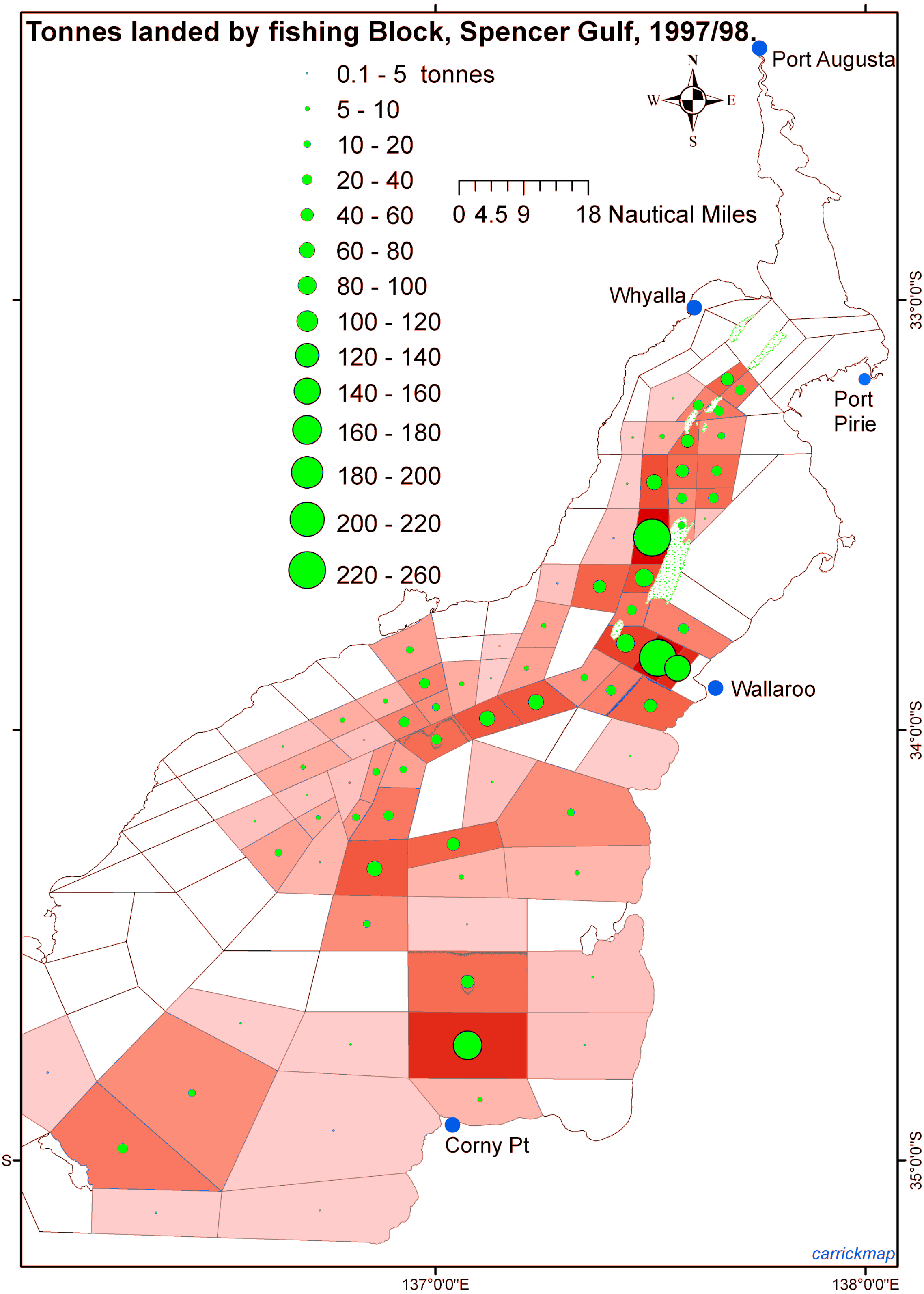


Figure 7.30: Prawn landings by fishing block in Spencer Gulf, 1997-98.

Landings in 1998-99 were 2 315 tonnes for 21 301 hours with an annual rate of 108.7 kg/h and the largest catch (233 tonnes) was taken from block 43 (Wallaroo; Figure 7.31).

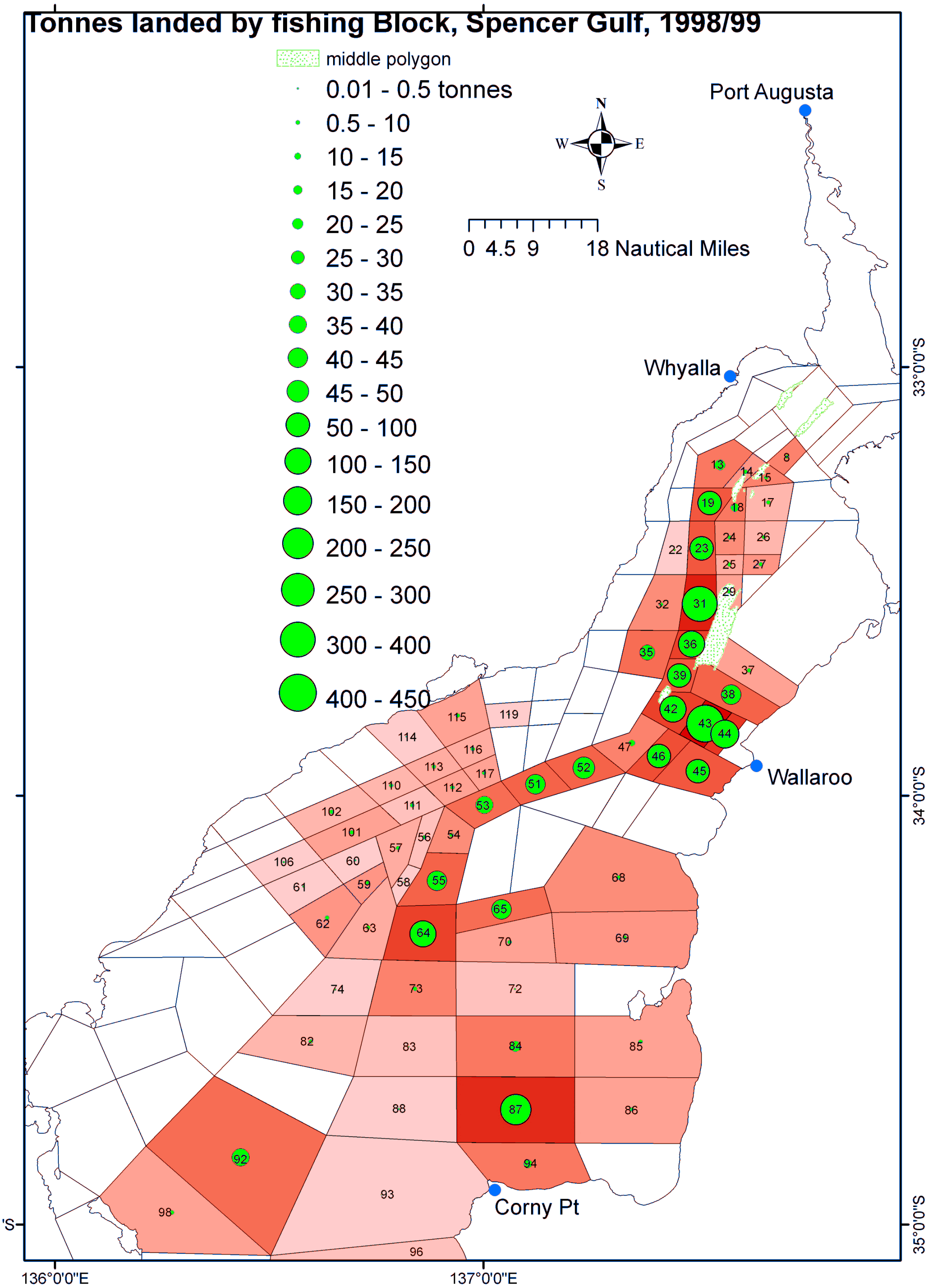


Figure 7.31: Prawn landings by fishing Block in Spencer Gulf, 1998-99.

Landings in 2001-02 were 2 182 tonnes for 19 843 hours with an annual rate of 110 kg/h. The largest catch was landed from Wallaroo ground (blocks 43, 44 & 45), Shoalwater (block

40), Gutter, Steamer Channel (blocks 51 & 50), Wardang and Corny Pt (blocks 87 & 68) grounds (Figure 7.32). No trawling took place north of block 31 in 2001-02 as prawns were below optimum target size, with trawl effort focused to an aggregation of large prawns in the Wallaroo region. For the first time in the history of the fishery, large catch and catch rates were landed from blocks 50 and 49.

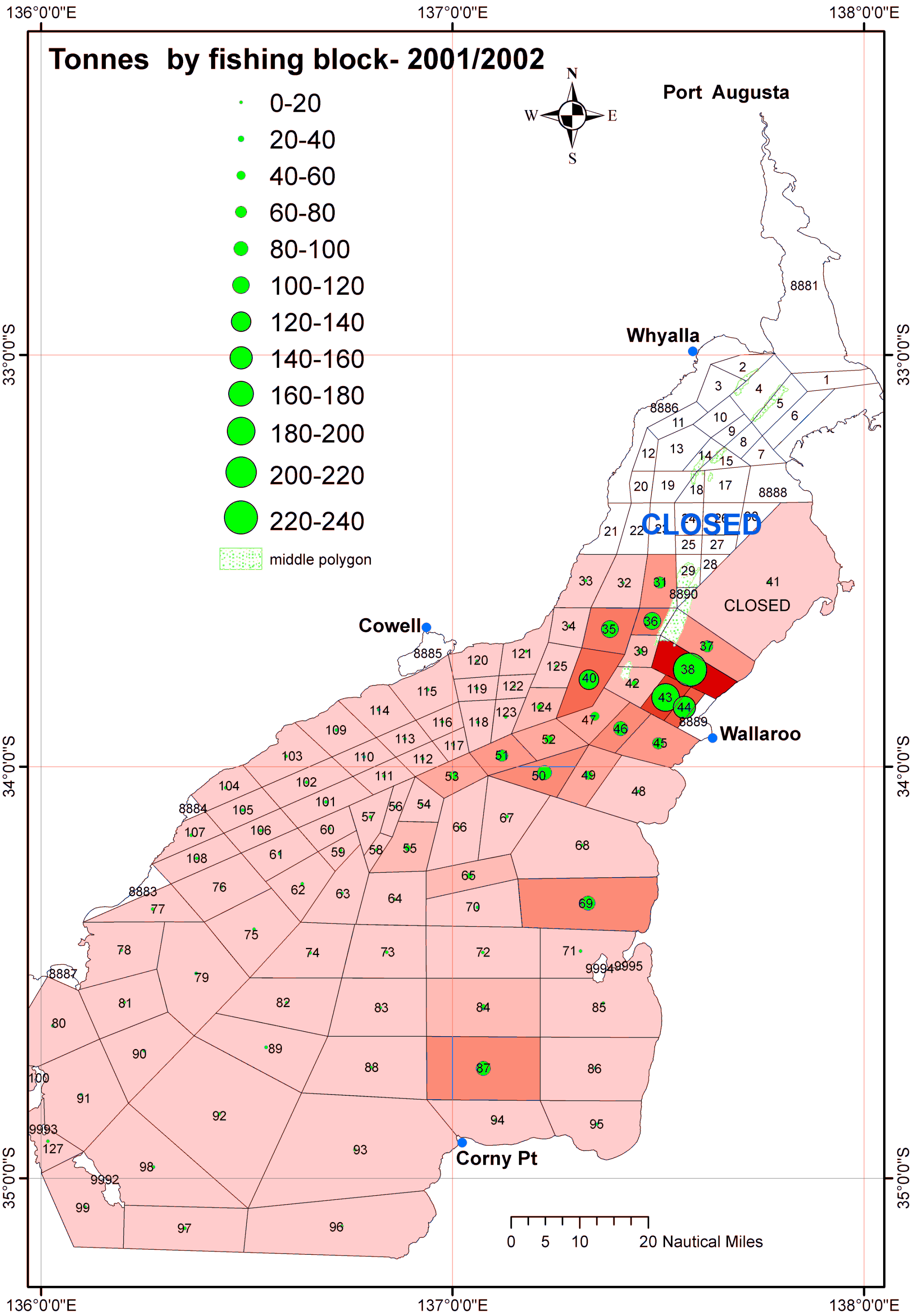


Figure 7.32: Prawn landings by fishing Block in Spencer Gulf, 2001-2002.

The spatial distribution of landings for 2001-02 viewed in 3D with main prawn movement pathways determined from mark-recapture studies is illustrated in Figure 7.33. The spatial patterns in landings in 2001/2002 and 1998/1997 are largely different to those of 1977-78, 1978-79 and 1980-81. The large peak in landings in 2001-02 is situated at the Wallaroo ground where prawn tagging has shown that prawns from the northern area and the northern sector of Cowell move into the region from February to May.

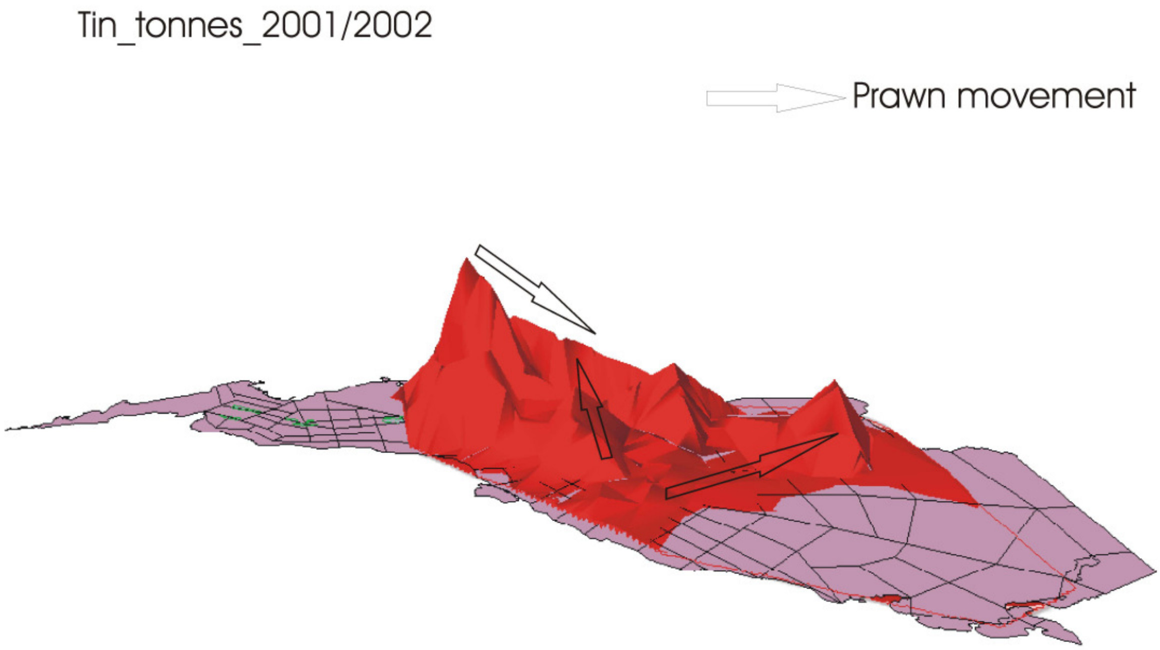


Figure 7.33: A 3D interpolation of the spatial prawn catch in Spencer Gulf in 2001-2002 showing main prawn movement pathways.

7.4.3 Main closures implemented from 1977-78 to 2002-03

In 1977-78, there was a permanent closure (1) in the northern section of the Gulf with the fishery open to fishing from January-December (Figure 7.34). In 1978-79, trawling was prohibited north of a line from Shoalwater Pt to Point Jarrold from February to 31 March to reduce the capture of very small prawns.

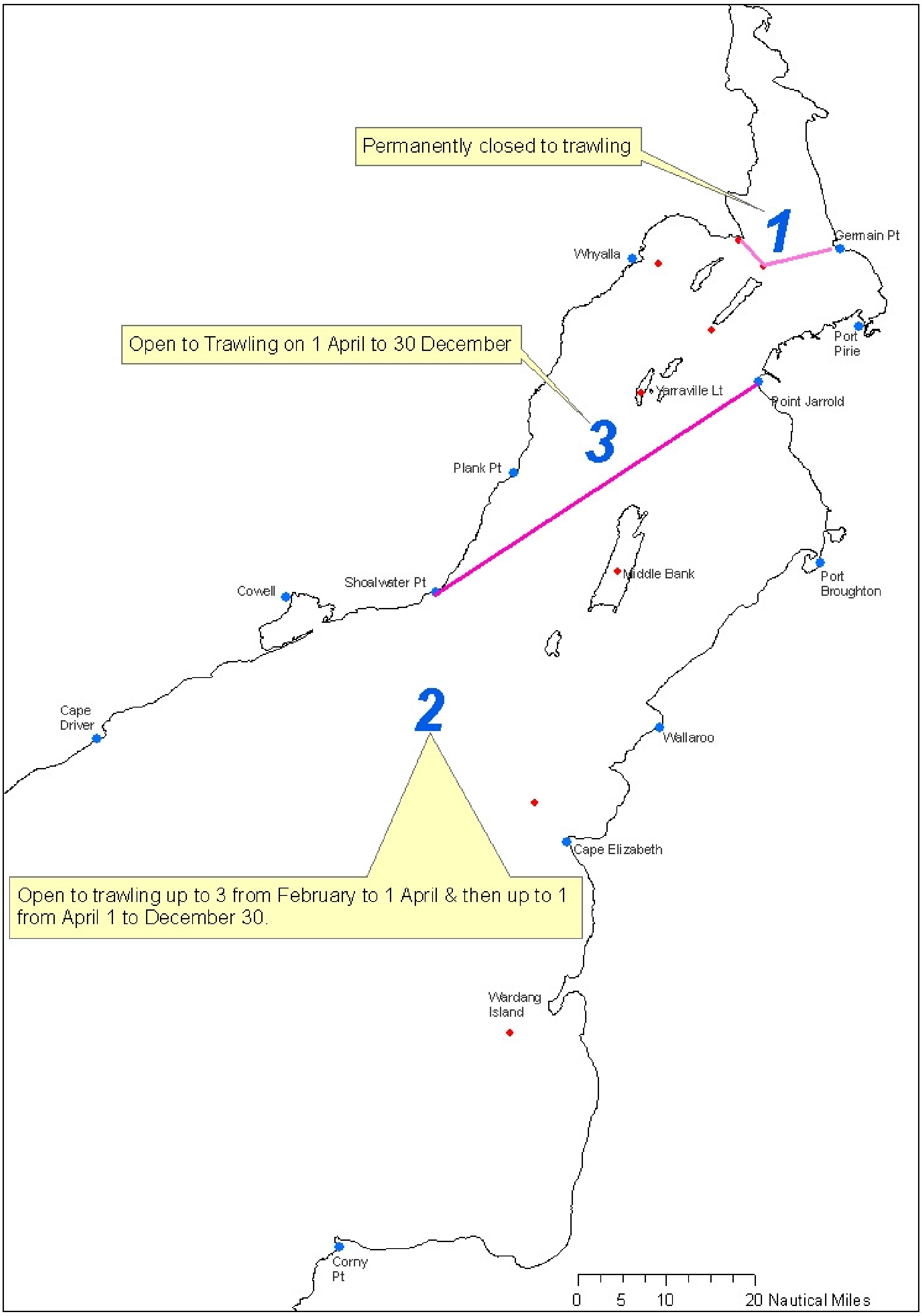


Figure 7.34: Fishery closures adapted in Spencer Gulf in 1977-78 and 1978-79.

In 1980-81, sequences of spatial closures were introduced in the northern section (4-7) of the Gulf (Figure 7.35). A second permanent closure (2) was proclaimed in the vicinity of Port Broughton to protect juvenile King George whiting. Additionally, a large of the Cowell area (3) was closed as an adaptive experiment to determine prawn movement pathways and whether prawn size composition and biomass would increase in adjacent areas with Cowell closed to fishing.

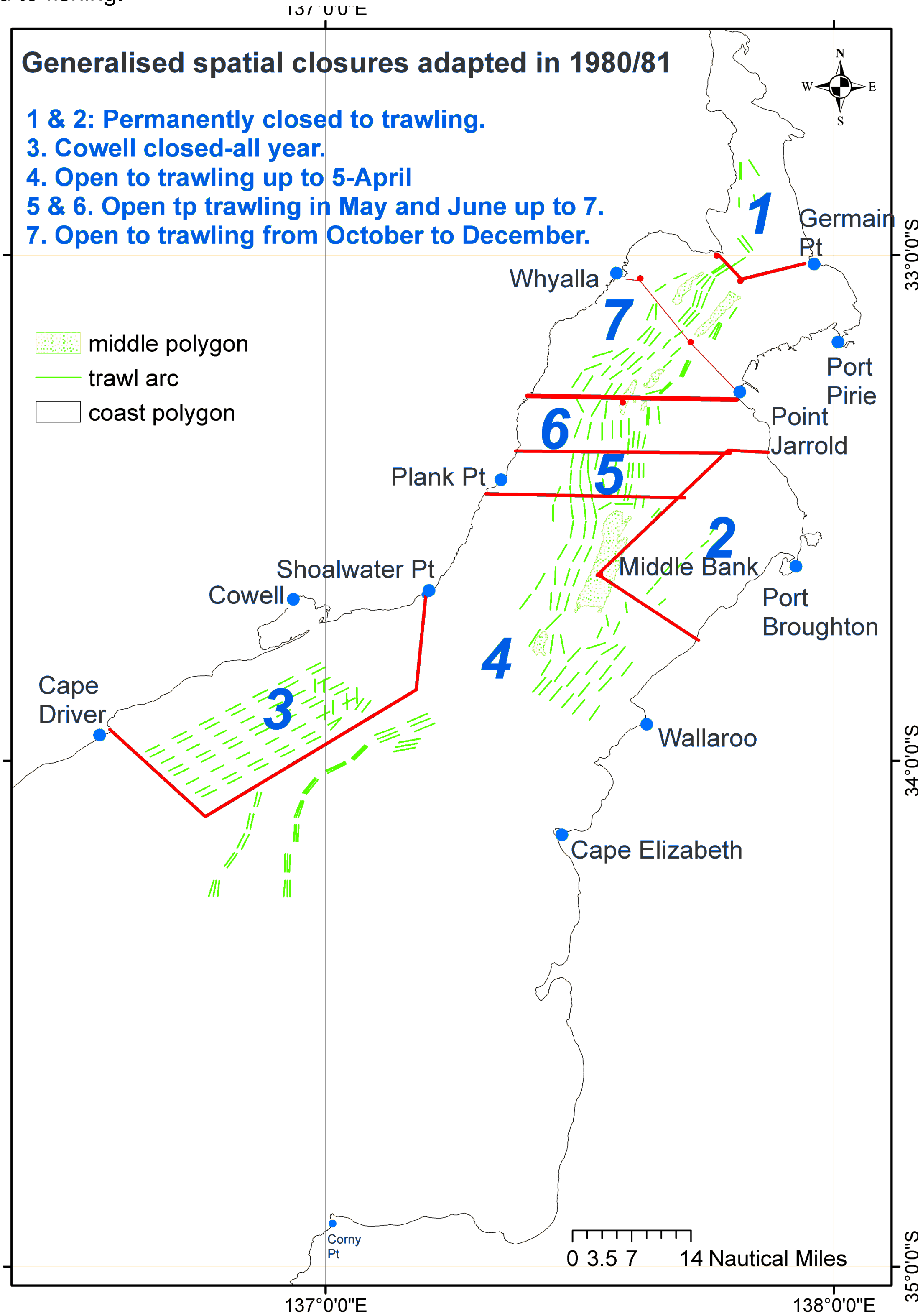


Figure 7.35: Fishery closures adapted in Spencer Gulf in 1980-81.

Numerous spatial closures were tested from 1980-81 to 2001-02 and are generalised in Figure 7.36. The closures were primarily aimed at increasing the size composition of catch, fishery sustainability and optimising the value of catch. It is beyond the scope of the report to provide details of the closures adapted but it is planned to document the different types of closures and the rationale implementation.

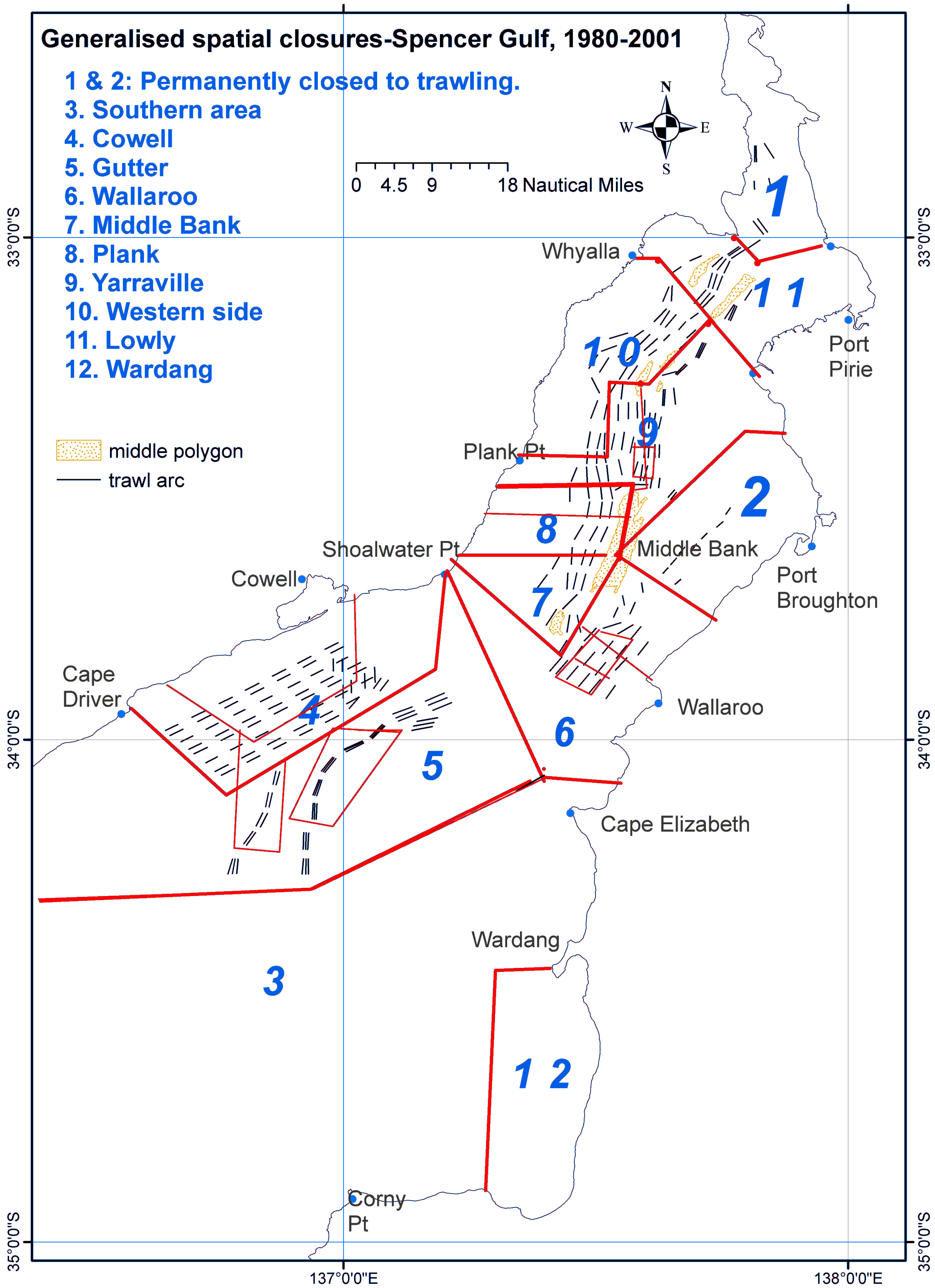


Figure 7.36: Generalised diagram of fishery closures adapted in Spencer Gulf from 1980-81 to 2001-02

7.4.4 Comparison of the size composition of prawns landed from 1978-1979 to 2001-02.

Spatial and temporal closures resulted in a reduction in nominal trawl effort and a substantial improvement in the size (and value) of prawns landed, as verified by information provided below. Prawn size composition data based on commercial grades (no/lb, head on) was obtained from processors and fishers. A comparison of the historical size composition of landings from 1978-79 to 1998-99 was undertaken to show the benefits of adaptive harvest strategies (Figure 7.37). Results show that there has been a large increase in the proportion of large prawns landed from 1978-79 to 1998-99 (and 2000-01) which was attributable to the development and refinement of harvest strategies.

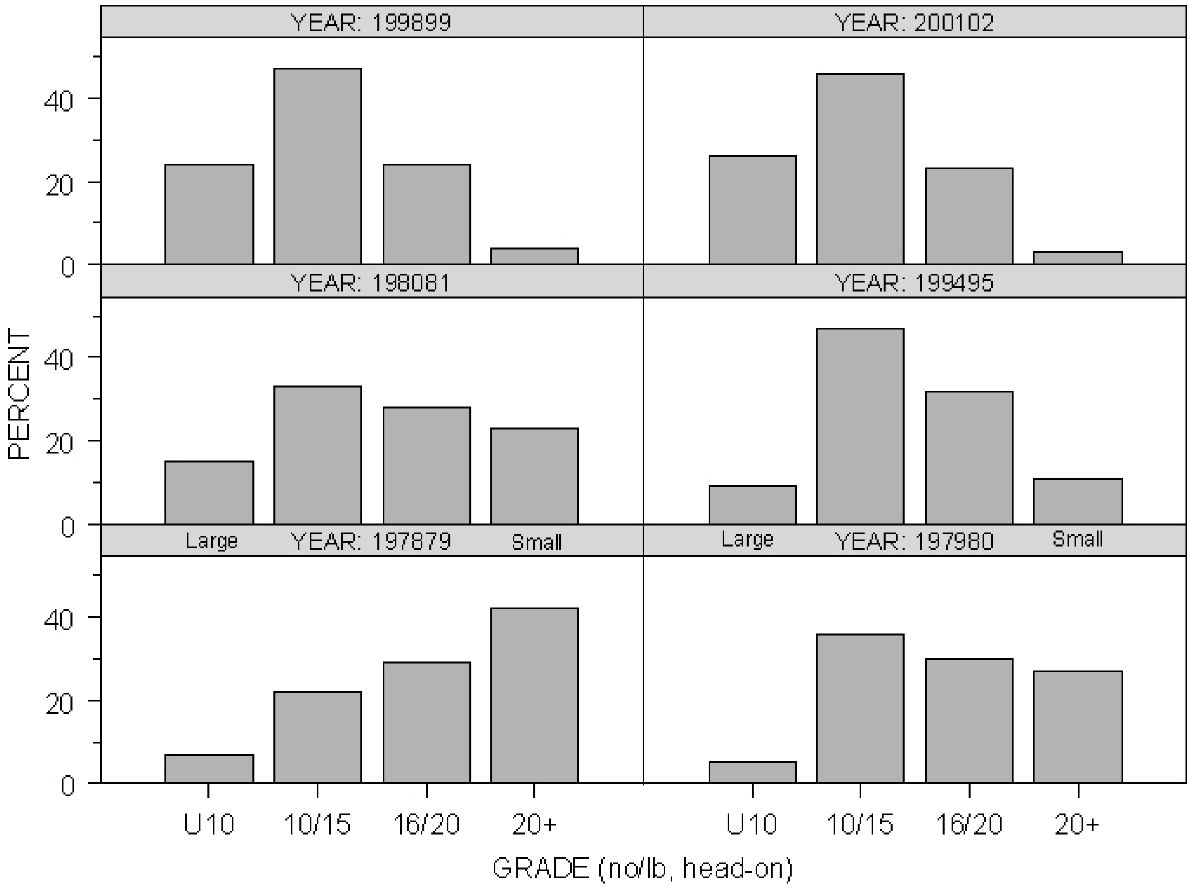


Figure 7.37: Historical patterns in the annual size composition of prawns landed in Spencer Gulf.

The proportion of smaller prawns landed (>20 prawns/lb, head on) fell from 42% to approximately 3% from 1978-79 to 2001-02 with a commensurate increase in larger grades from 29% to 73%. The increase in the size (and quality) of catch and reduction in “wasteful” effort from 1978-1979 to 2001-02 resulted in substantial gain in the value of the fishery and fishery sustainability. Tagging and trawl survey studies have shown that premature harvesting of smaller prawns at key regions would have reduced the supply to important areas where larger prawns are captured and reduced the ‘spread’ or dispersal potential of the population.

Understanding the seasonal movement and dispersal, spatial size distribution and growth patterns of prawns has largely assisted in the development and refinement of harvest strategies, with an active role played by industry in the research.

7.4.5 The need for reliable point data for visualisation of catch and effort data and stock assessment.

The spatial distribution of landings in tonnes (square root transformed) by latitude and longitude requires careful interpretation (Figure 7.38 and Figure 7.39). Landings from the Cowell ground have similar latitude to the Wallaroo fishing areas. Similarly, for longitude, the Wallaroo ground has similar longitude to areas in the north where large catches of small prawns occurred in 1977-78 and 1978-79. However, one can see that there has been a large reduction in landings from the northern section (33.0 – 33.4° S) of the Gulf from 1977-78 to 2001-02. Spatial Landings increased with longitude from 1977-78 to 2001-02 due to larger catches taken in the eastern sector of the Gulf in the vicinity of Wallaroo and Corny Pt.

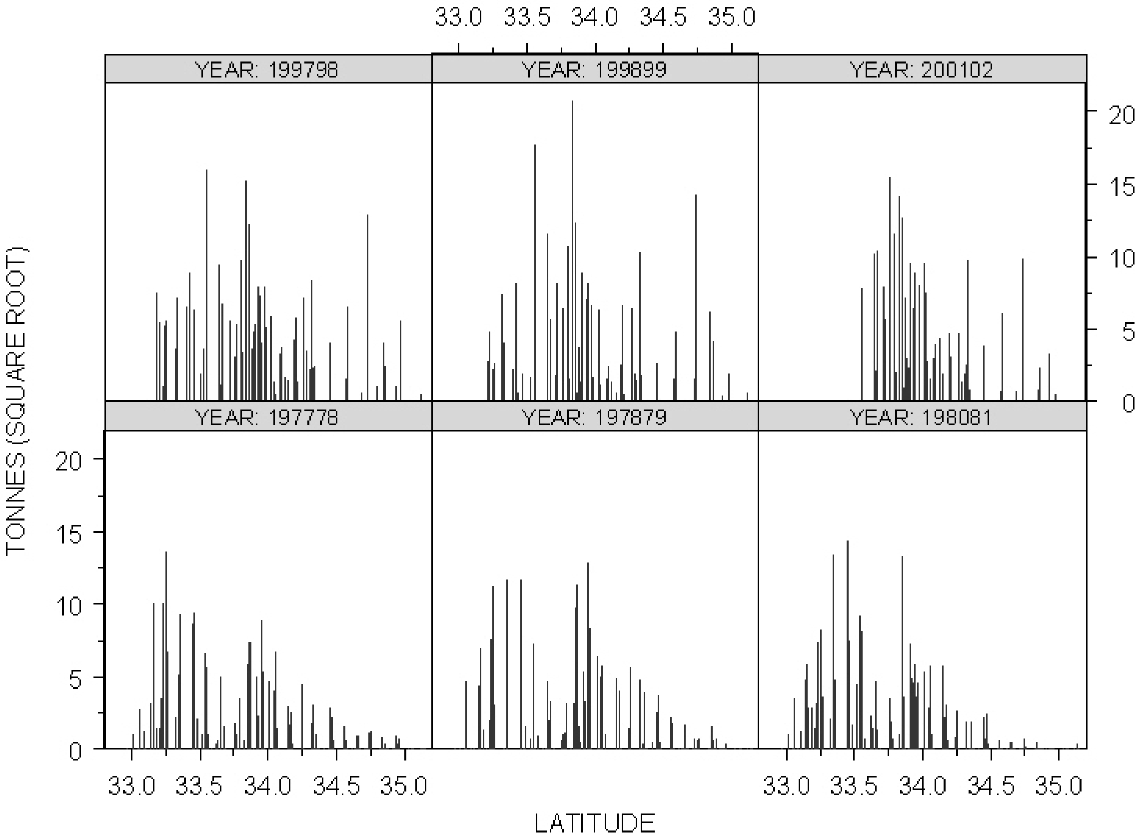


Figure 7.38: Comparison of the distribution of prawn landings (square root tonnes) over latitude (decimal degrees) from 1978-79 to 2001-02.

Better visualisation of spatial patterns and more accurate stock parameters can be obtained by interpolation using actual trawl point data with boundary shape file restrictions. The midpoints of each fishing block were derived from centroids of blocks which varied largely in area and shape. For many blocks in the southern area of the Gulf where block size is large, the centroids do not provide a reliable representation of where fishing takes place, and in many cases, where block sizes are large, the distribution of catch and effort is not spatially representative and CPUE is biased. For example, less than 10% of block 64 and less than 40% of block 87 is trawled but it appears from Figure 7.32 that the prawn catch occurred evenly over the entire blocks, whereas it was confined to a number of strips (personal observation).

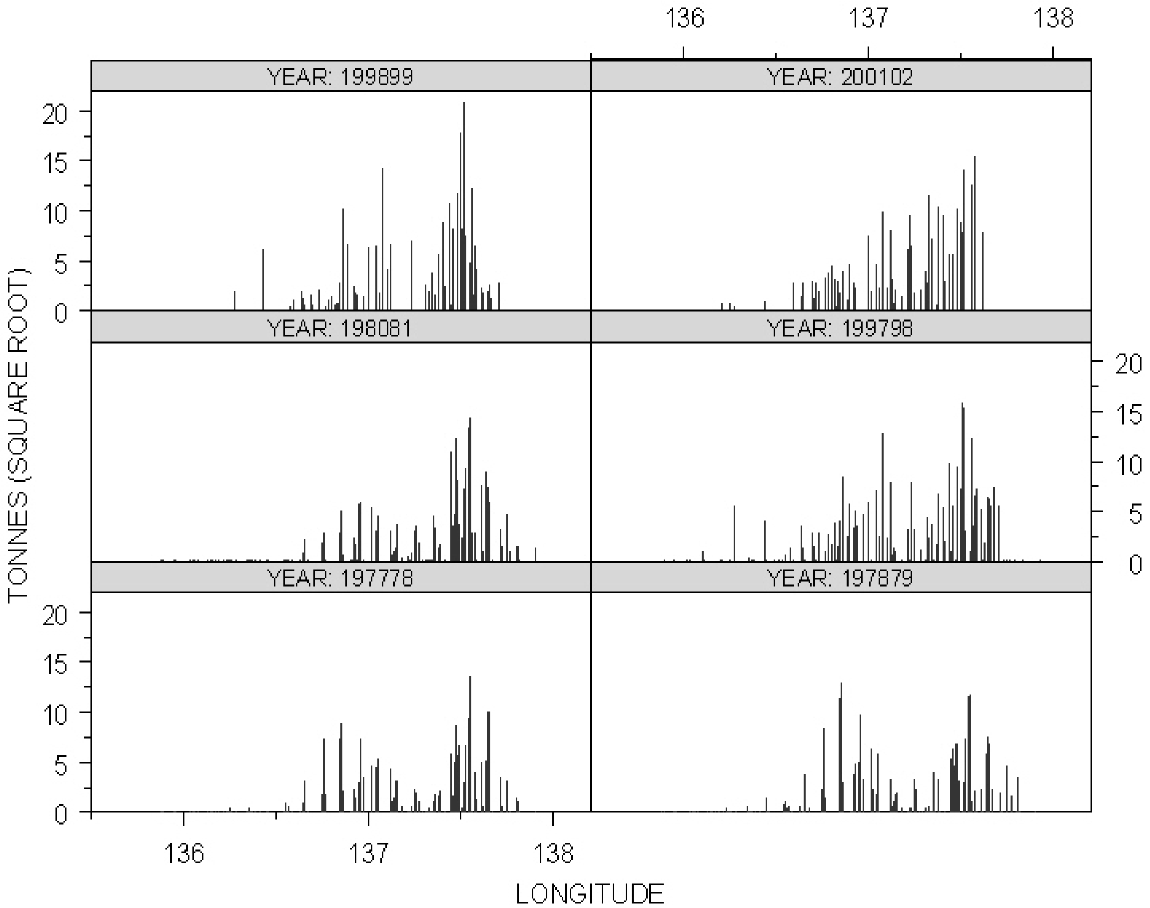


Figure 7.39: Comparison of the distribution of prawn landings (square root) over longitude (decimal degrees) from 1978-79 to 2001-02.

The estimation of prawn density and modelling of fishery parameters (e.g., depletion rates) requires the incorporation of area, either as a weighting factor or as a covariate using actual trawl point data for estimation of the actual area trawled within fishing blocks. The problem was addressed at an industry general meeting with a view to improving the stock assessment, and visualisation of catch and effort temporal patterns as part of the FRDC project, (Carrick *et al*. 2000). It was recommended that finer scale spatial data be obtained from daily catch and effort logbooks by recording of point data (GPS locations) from trawl shots at least 3-times per night from the fleet, (see below). It was believed that point data derived from the mid-point of trawl shot locations (latitude, longitude) with catch, effort and cpue would provide a better data source for interpolation and visualisation of catch and effort data, compared to using the centroids of fishing blocks. With the support of PIRSA and industry FMC members, the recording of prawn size data (grades) and GPS trawl shot locations in daily catch and effort logbooks (at least 3 trawl shots and change fishing blocks) was made mandatory in 2002 for the Spencer Gulf prawn fishery, (Appendix 2). An Oracle database was developed for the entry of GPS trawl shot locations and the entry of the paper forms was undertaken by SARDI, which proved most difficult due to a number of factors. The location of trawl shots from the 2002-03 logbook data is shown in Figure 7.40, each point being associated with the fishing block recorded by fishers.

Results demonstrated that there are numerous errors in trawl location data, as indicated by many trawl shots on land and in closed areas. Errors occur in the recording of GPS data on logbook forms by fishers and in entry of data from logbook forms. It would be more efficient and accurate to introduce an electronic data capture method for daily and monthly catch and effort logbook data. An attempt was made to develop and test the electronic data transfer of daily logbook data using CDMA. However, this was not possible because of insufficient support from industry, although sending summary survey data by CDMA from vessel to shore proved successful when tested.

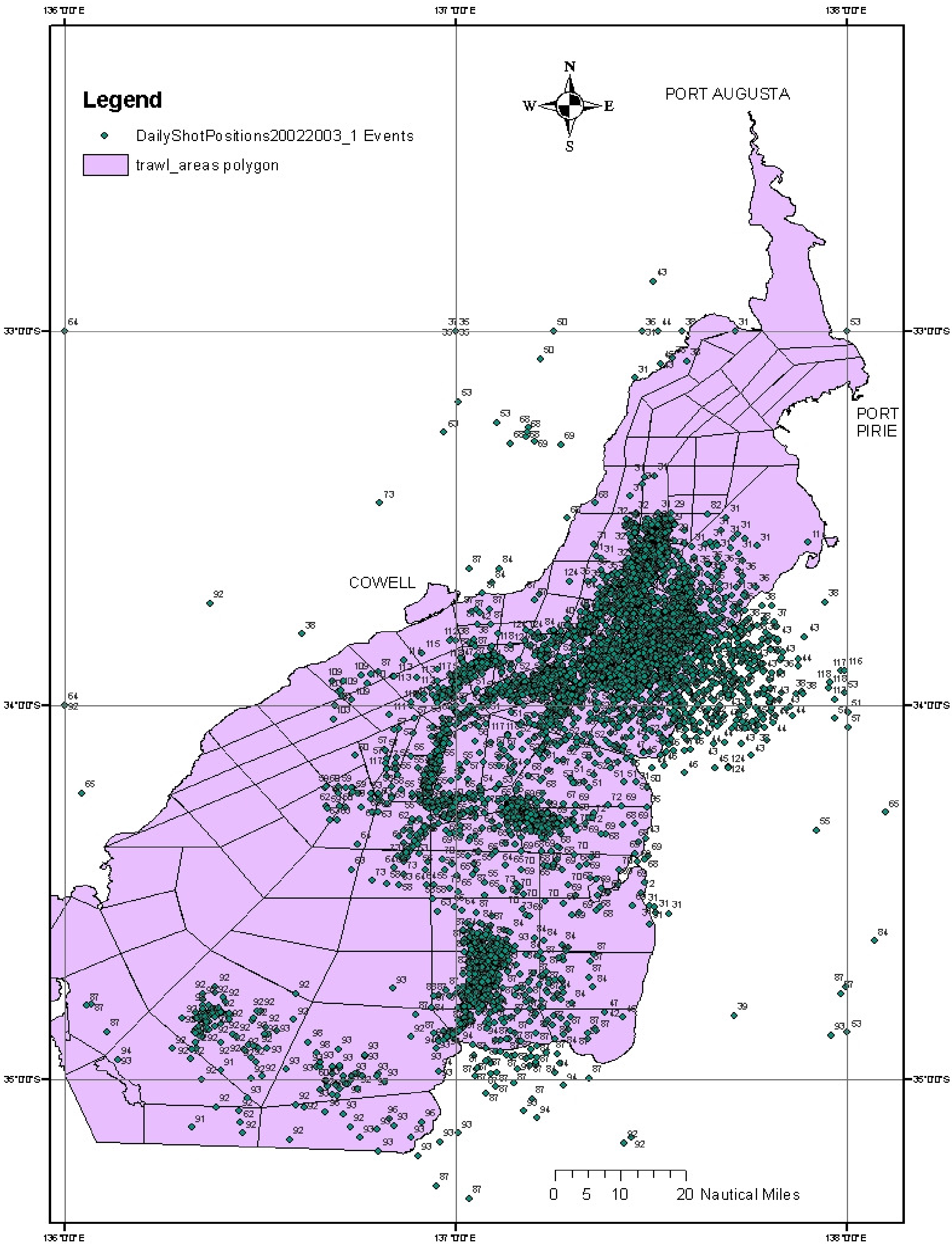


Figure 7.40: Spatial distribution of Spencer Gulf prawn fishery trawl shots from GPS positions provided by fisher's daily logbook returns over 2002-2003.

7.5 Case study of real-time management for fishery sustainability in Spencer Gulf

7.5.1 Introduction

Trawl surveys are conducted at pre-determined locations over 1-3 days prior to commercial fishing. Owing to the dynamic nature of the stock (e.g., 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. These are implemented by Ministerial delegation by faxing and emailing hard and electronic copies to the fleet with information broadcast by a radio base situated in the main port at Wallaroo (Appendix 3b & 3c). The fleet works in the night with harvest strategies frequently developed and closures implemented overnight or early morning. The Coordinator at Sea has an important role in coordinating discussions with operators and communicating information to a shore base maintained by a fishery scientist who develops harvest strategies in collaboration with PIRSA Fisheries and the Committee at Sea (CAS).

The Spencer Gulf prawn fishery is recruitment-driven with limit (or threshold) biological reference points used to gauge fishery sustainability, determine 'optimum' harvest strategies and the need for constraints on catch and effort. Threshold biological reference points were developed to prevent fisheries from being over-exploited, with detailed accounts of methodologies provided by Quinn and Deriso (1999), Smith *et al.* (1993), Mace (1999) and Myers *et al*. (1994), among others.

In February 2003, a fishery-independent trawl survey indicated a significant decline in biomass density of stock and recruitment. This was reported at a meeting with industry in March 2003, after the February 2003 survey and prior to fishing, with recommendation for constraints on exploitation from March-June, and with a review of the status of the stock in October and November 2003, prior to fishing in November when prawns start breeding. It was pointed out that:

- The analysis of annual biomass (catch rates) trends indicated a stock decline in February 2003.
- The recruitment level in 2003, in the main recruitment area, was low and at the critical (or threshold) level.
- There was a need for immediate management action to reduce exploitation from March-June 2003 and especially over the reproductive maturation and spawning period from November-December.
- There was a need to assess the amount of spawning from October-December and to develop harvest strategies which provided greater scope for spawning without closure of the fishery.
- The value of catch must be maximised to obtain price premiums for larger prawns and seasonal changes in demand.

The recruitment level in February 2003 was shown to be at the limit reference point level where management action was required by the FMC to ensure the health or sustainability of the fishery. In October 2003, surveys were initiated to monitor prawn spawning using macroscopic staging of female prawn maturation stages. The results indicated that negligible (<5%) spawning had occurred by late October. It was recommended that fishing be delayed to increase the potential for spawning and exploitation should not occur until the completion of a survey to assess the biomass and the spawning status of the stock in November 2003. An FMC meeting took place some 10 hours after the completion of the November 2003 survey where results were discussed and harvest strategies developed. This meant that trawl survey data (biomass density and spawning status) had to be assembled, entered into a database and analysed within an 6 hour time-frame for presentation of results and recommendations to the FMC. Such a rapid response could only be achieved by having and effective database system linked to statistical and GIS mapping tools and effective real-time communication (email, facsimile and mobile phone) with the survey vessels).

7.5.2 Recruitment and biomass density in February 2003

Fishery-independent trawl survey data was used to estimate the annual recruitment in February 2003 and compare it with the reference point threshold, which has an index of 35 (see above). The main region for the assessment of recruits in Spencer Gulf is situated in the northern part of the Gulf, where abundance is highest and more variable (Figure 7.41). Mean recruitment in 2003 was compared to the baseline year 1987 and means from 2001-02 to determine the 'health' of the fishery in February 2003.

Data on recruit numbers was square root transformed to homogenise variance, and subjected to mixed model analysis with sea water temperature incorporated as a covariate. An assessment of the risk that recruitment was less than the threshold level was undertaken by:

- Determination of the best distribution fit of the data.
- Determination of the percentage of distribution less than the reference point based on value – 35 recruitment.
- Bootstrap simulation of recruit indices based on 1 and 0 for values <35 and >35, respectively, for determination of the risk that recruitment was lower than the limit reference point.

Comparisons of February and November mean annual biomass density, expressed as lb/minute (for fishers preference) were made using a mixed model application in REML based on a fixed model testing the effect of Year, Region and the Year x Region interaction (Figure 7.42).

The comparison of annual biomass density for November surveys incorporated water temperature as a covariate to reduce bias, as differences in water temperature are known to influence prawn catchability (or availability, see below) in the October-November period, (unpublished). The Oracle database facilitated the fast output of data files required for data analysis. Statistical analysis was undertaken using residual maximum likelihood (REML) and computer intensive applications using SPLUS with an ASREML "bolt on". Explanations of mixed model statistical frameworks and applications are provided in Verbyla (1993), Gilmour *et al*. (1995) and Verbyla *et al*. (1998), among others. The linear mixed model formulation is best described by matrix formulation as:

$$y = X\tau + Z\mu + \varepsilon$$

where y is the data vector of length *n*, X and Z are design matrices, τ and μ are *p* and *q* vectors of fixed and random effects and ε is the error term.

A mixed model, based on REML, is more appropriate for the analysis of data that is unbalanced and spatial. Furthermore, it allows greater proportional sampling for the estimation of means from sub-populations (e.g., Regions) where the size of areas is different; thereby providing scope to increase replication within regions where density and variances are highest.

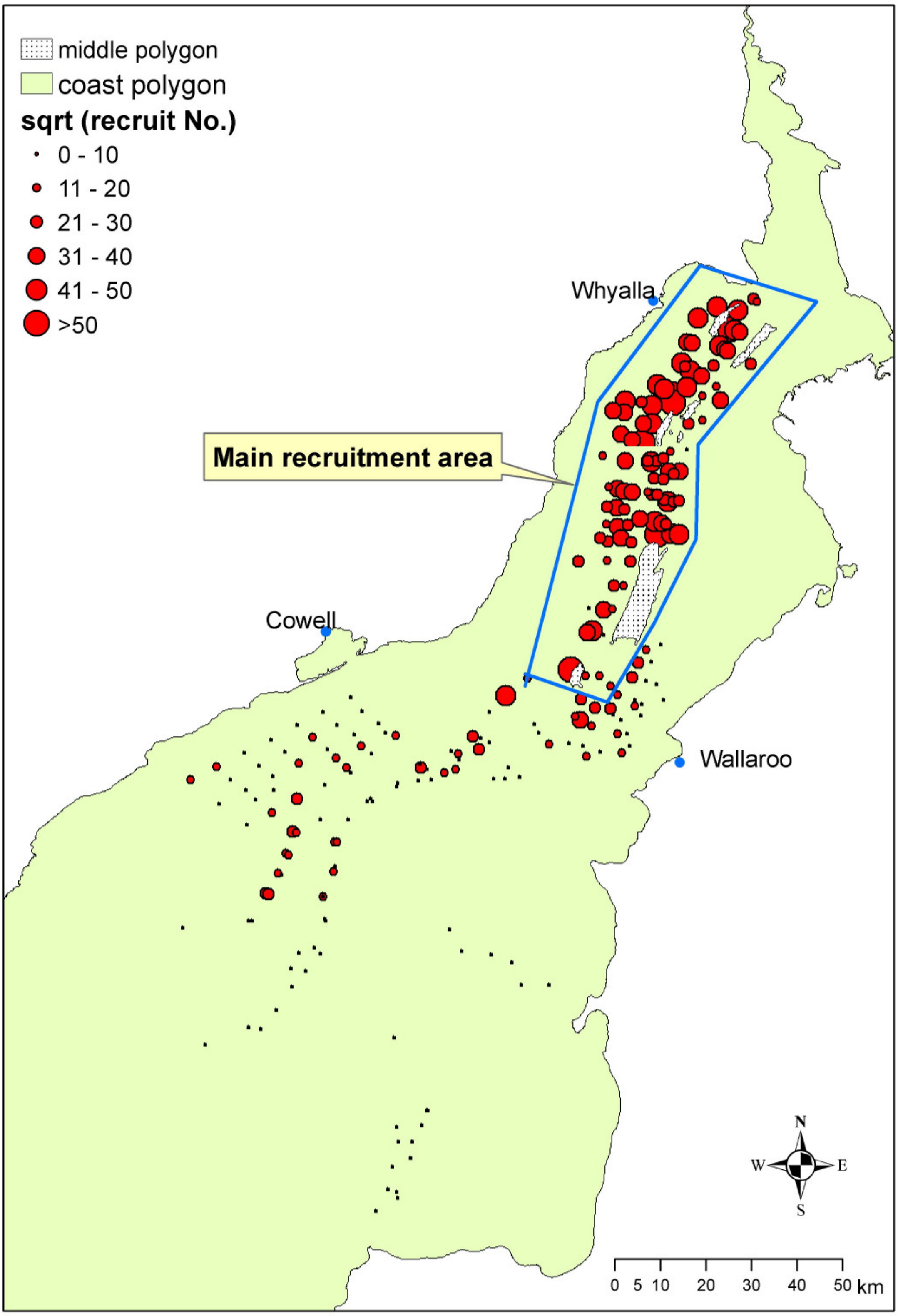


Figure 7.41: Spatial location of fishery-independent trawl sites (N = 240) showing the main recruitment area of Spencer Gulf.

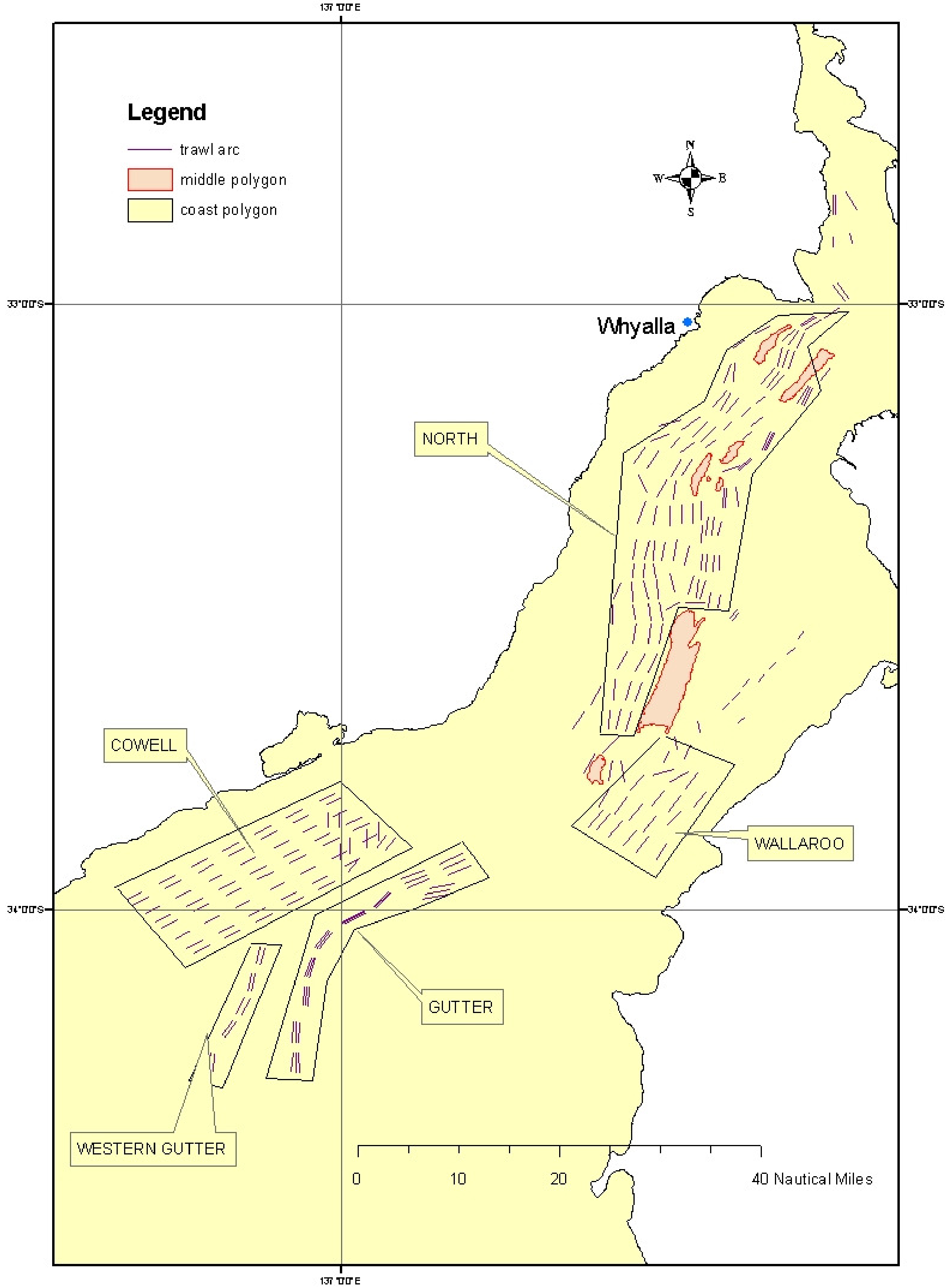


Figure 7.42: Location of main trawl locations for comparison of annual biomass density trends from February and November surveys, Spencer Gulf.

7.5.3 Results

February 2003 recruitment

Mean recruitment indices based on February trawl surveys from 2001-03 were compared to a "base year" (1987) which had low recruitment (Figure 7.43) and fishery production.

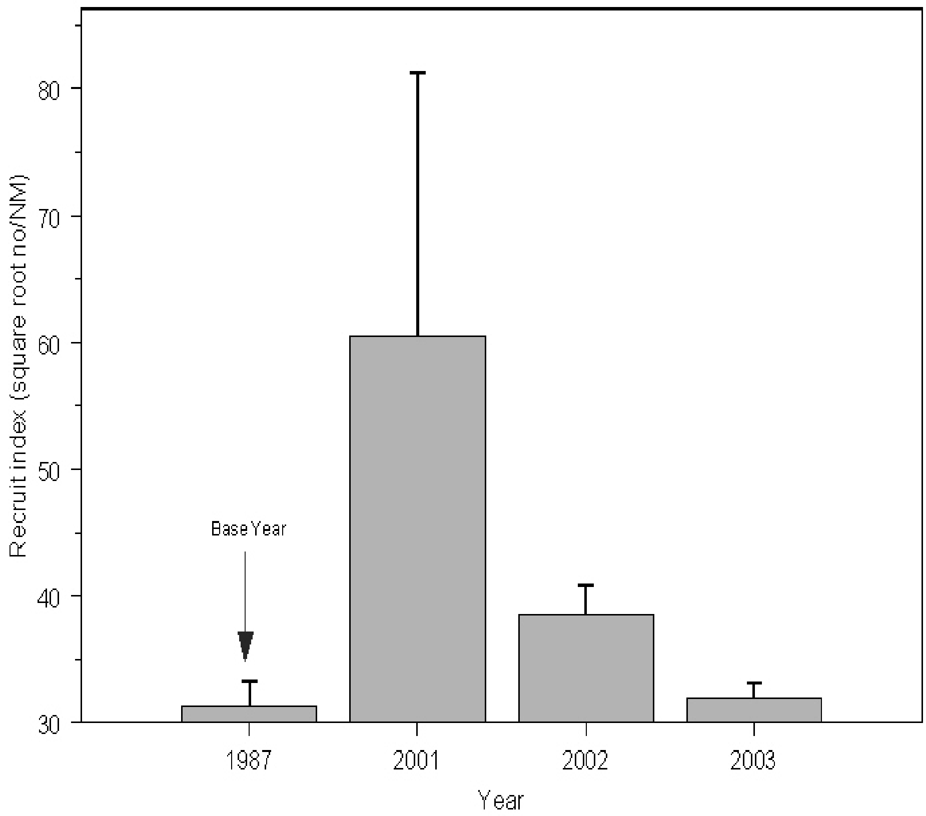


Figure 7.43: Comparison of mean (standard error) recruitment indices in the Spencer Gulf prawn fishery between 2001 and 2003, in contrast with 1987.

The results showed that there was a statistically significant ($p<0.001$) decline in recruitment from 2001 to 2003. Recruit data from the February 2003 survey was fitted to density distributions using Monte Carlo simulation (500 iterations). The Kolmogorov-Smirinov test (K-S), a measure of the deviation from the fitted model, showed that the normal distribution was the best fit to data (test value = 0.053, $p>0.15$). The mean recruitment index was 31.92 ± 1.26 which was lower than the limit reference point of 35 and not significantly ($p>0.1$) different from the 1987 baseline year (Figure 7.44 A). When recruit indices data was truncated over the range limits (4-71) approximately 59% of the distribution was ≤ 35. A cumulative probability distribution of recruit values illustrates the good fit to the normal distribution with a probability of 0.6 that recruit indices in February 2003 were ≤ 35 (Figure 7.44 B).

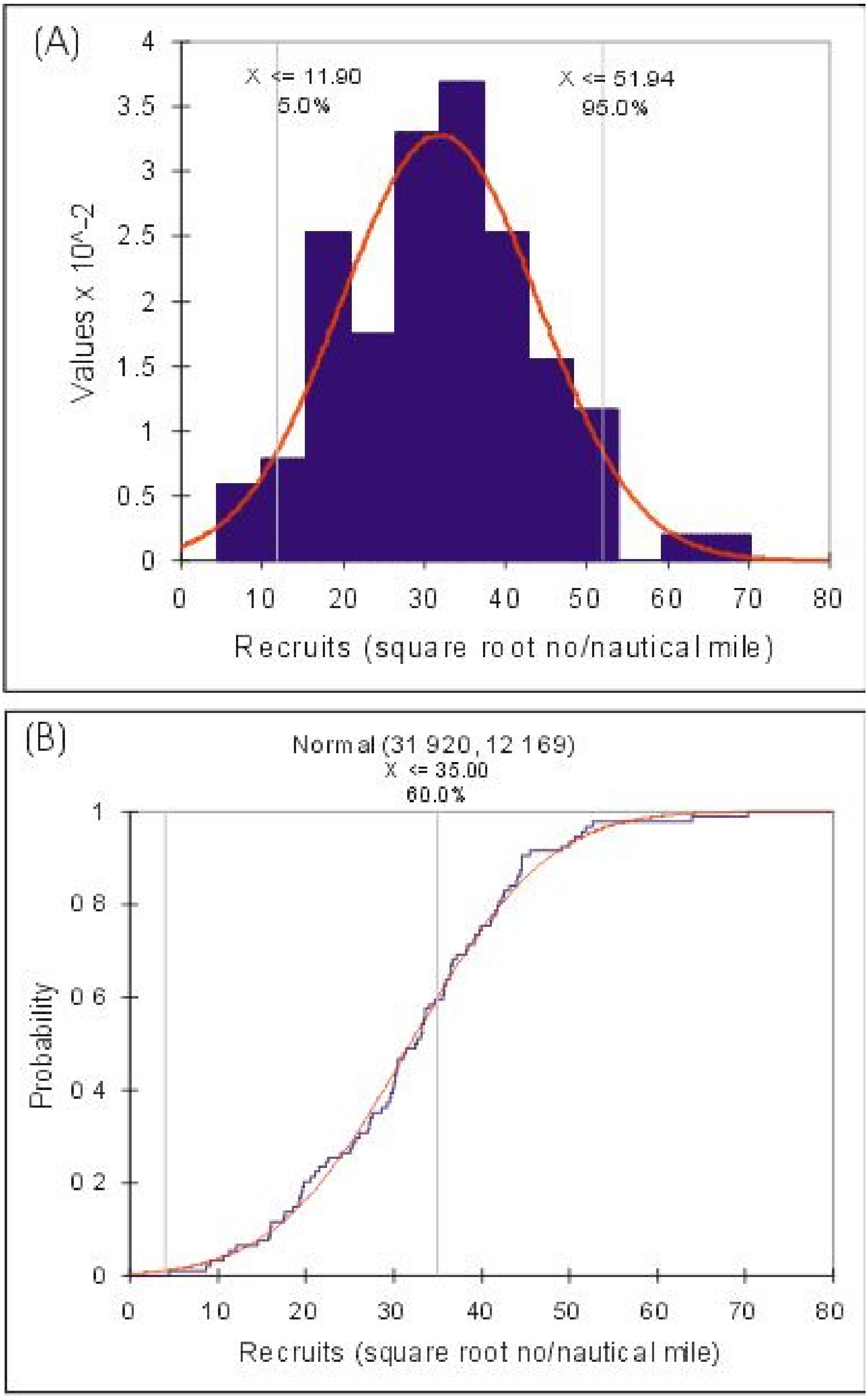


Figure 7.44: February 2003 recruitment indices fitted to (A) a normal distribution and (B) a cumulative probability distribution with truncation of the recruit value range from 4-71.

The estimation of the risk that recruitment was <35 using a distribution free bootstrap simulation (Efron and Tibshirani 1993) was on average probability, 0.598 ± 0.052, suggesting that there was a 44-65% chance that recruitment was below the limit (threshold) reference point where management action was required by the FMC to ensure future stock sustainability.

Exploratory data analysis of biomass density (lb/min) was carried out by obtaining mean estimates for each year by pooling all regions with the same sampling sites from 1987 (N = 110) and graphing mean and standard errors (Figure 7.45). Data was square root transformed and subjected to Reml to test Year + Region + Year.Region effects. The biomass density in 2003 was statistically lower (p<0.001) than all years used in the comparison, except 1987, which was a 'base year.' For the Northern region, the biomass density in February 2003 was significantly (p<0.001) lower than all years except 1987.

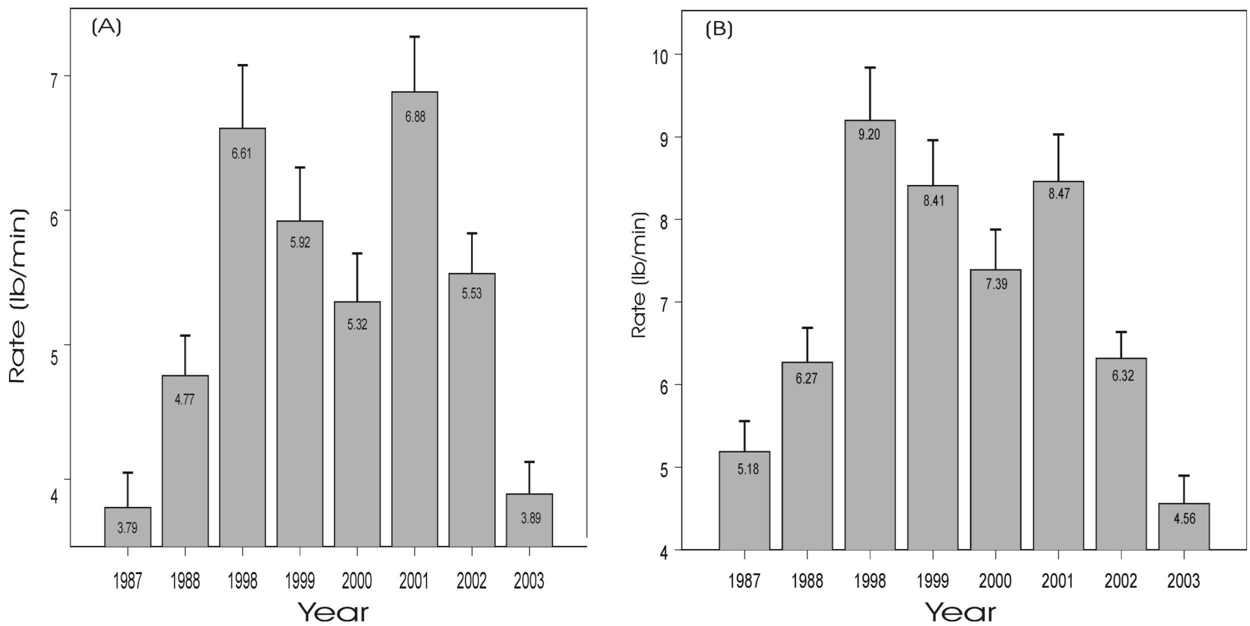


Figure 7.45: Comparison of February survey biomass density of stock (lb/min) in Spencer Gulf in 1987 and 1998-2003- (A) All sites (N = 110) and (B) Northern area sites (N = 76).

Comparison of November biomass density, 1997-2003.

Surface sea water temperatures were recorded for each survey station from 1997-2003. Results showed that temperatures in November 2003 were significantly warmer than in other sampling periods (Table 7.11 A). Warmer water was likely to influence prawn catchability and bias biomass estimates if analyses were not 'indexed' using temperature as a covariate. Residuals from REML were plotted for untransformed and square root transformed data with the transformation providing best fit to a normal distribution. Results from the REML analysis of biomass density from 1997 to 2003 with water temperature as a covariate show that the stock in November 2003 was at least 66% lower than the 6-year average from 1997-2002 and was about 58% lower than 2002 (Table 7.11 B1&2). The SPLUS with ASREML 'bolt-on' analysis shows that there was a 78.8% reduction in biomass density in November 2003 compared with the 6-year mean and a 75.3% decline in biomass density in 2003 compared with 2002 (Table 7.11 C). The covariate, water temperature, was significant (p<0.001) with a one degree increase in water temperature increasing the biomass density by 0.899 ± 0.157lb/min.

Table 7.11: Comparison of mean biomass density (lb/minute) over October/November prawn surveys in Spencer Gulf, 1997-2003.

A	**Applications**										
		1997	1998	1999	2000	2001	2002	2003	sed	% decline mean v 2003	%decline 2002 v 2003
	Unadjusted biomass means	3.46 (0.04)	5.02 (0.23)	3.74 (0.19)	3.32 (0.18)	4.47 (0.21)	2.83 (0.17)	2.73 (0.14)			
	Mean water temperature	17.53 (0.04)	18.35 (0.06)	17.87 (0.05)	17.48 (0.05)	17.45 (0.04)	16.92 (0.06)	19.21 (0.06)			
B	**REML model structure-square root transformed data.**										
		1997	1998	1999	2000	2001	2002	2003			
1	Vcomp[Year+temp] Region.Rep	1.88	1.84	1.79	1.86	2.13	1.88	0.93	0.07		
	Back transformed mean	3.52	3.40	3.19	3.46	4.55	3.53	0.86		76.2	75.7
2	Vcomp [Year*Region+temp] Region.rep	1.67	1.88	1.68	1.61	1.93	1.55	1.00	0.08		
	Back transformed mean	2.80	3.52	2.83	2.58	3.71	2.40	1.00		66.2	58.2
C	**SPLUS with ASREML Fixed=rate~-1+Year+temp, random=~Region+Region:Year+Region:Rep+Region:Year:Rep**										
	mean	3.19	3.95	2.99	2.86	4.00	2.87	0.71		78.6	75.3
	Standard error	0.51	0.52	0.51	0.51	0.51	0.52	0.56			
	Temp=0.899(±0.157)										

*A-mean biomass (lb/minute) and mean water temperature (℃) over Year ; B-REML models 1 & 2 using square root transformed data with water temperature as a covariate, standard error of difference (sed), back-transformed means with the percentage decline in biomass density in 2003 compared with 6 year mean and the 2002 mean; C-SPLUS with ASREML means and standard errors with water temperature as a covariate using untransformed data.

Prawn spawning estimates, October to December 2003.

Trawl surveys conducted in October, November and December to assess the reproductive maturation and the 'spawning status' of the stock used 3 replicate stations sampled over 2 regions (North and Wallaroo). Approximately 200 female prawns from each site were reproductively staged and measured at each sampling. The stages consisted of: 0 (virgin, spent), 1-2 (developing), 3 (early ripe) and 4 (ripe). Reproductive maturation expressed as a percentage of numbers over each stage for the 3 periods and 2 study areas (North and Wallaroo are shown (Figure 7.46).

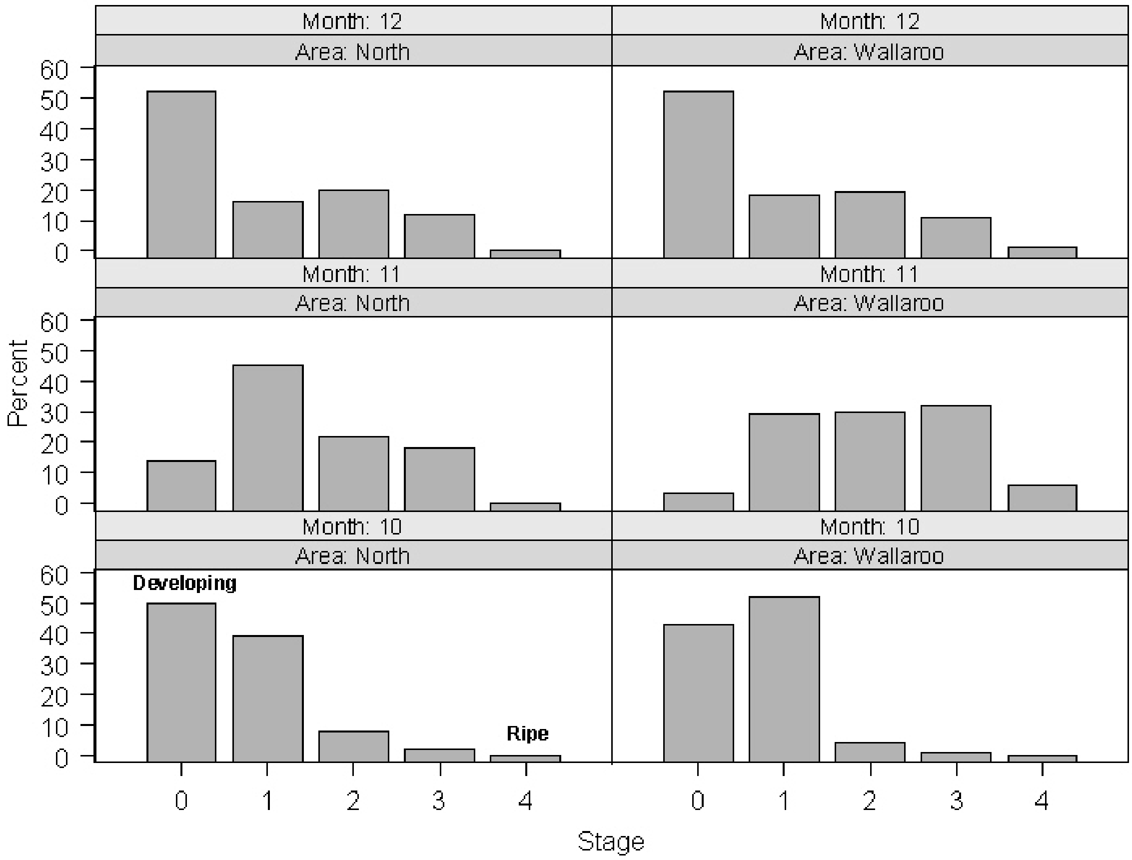


Figure 7.46: Female prawn reproductive maturation over 2 areas (North & Wallaroo) in October, November and December 2003.

By differentiating between stage levels over each sampling period, it was estimated that approximately 40% of the population in the northern area would have spawned between 20-11-2003 and 18-12-2003 and about 53% of the population in the Wallaroo sites. That is, spawning took place before intensive trawl effort was applied in December. It was unlikely that >10% of the population would have spawned before harvesting in the November fishing period which was constrained to a short duration (6 days). It is noted that reproductive maturation and spawning is strongly influenced by water temperature. For tiger prawns in the tropical latitudes, it has been estimated that it takes about 2 weeks for a female prawn at the ripest maturation stage (stages 3- 4) to spawn, (P. Crocos, personal communication). In contrast, for the colder waters in Spencer Gulf, it is expected that it would take a longer period for stage 3-4 female prawns to spawn.

7.5.4 Benefits of adaptive harvest strategies

Recruitment in February 2003 and biomass density in November 2003 showed significant declines compared to past seasons, warranting action by management to ensure fishery sustainability.

The delay in harvesting and constraints on exploitation over November and December 2003 would have increased the likelihood of increased spawning and therefore the sustainability or "health" of the fishery. The main objective of the harvest strategies developed in November/December 2003 was to delay fishing in November to provide the stock with a greater chance of spawning before capture in order to obtain >30% spawning before intense fishing in December 2003.

The survey results, including biomass density and the spawning status of the stock in November 2003, were discussed with the industry FMC sub-committee to develop a harvesting strategy. The low amount of spawning (<10% of sampled population) and the low biomass of stock in November 2003 were of major concern to management. PIRSA were advised that the sustainability of the fishery was at risk and constraints should be placed on trawl effort and catch over the November to December 2003 harvesting period for the following reasons:

- Recruitment in 2003 was below the lower biological limit specified in the Management Plan.
- The biomass of spawning stock in November 2003 declined and was at least 66% lower than the 6 year average and at least 50% lower than 2002 when 17 days were available to fishing in the November-December period.
- Insufficient spawning had taken place in November 2003 and it was suggested that total effort for November-December be reduced (by at least 30%) with main effort directed to the December fishing period (rather than November) to increase egg production.

The restrictive harvesting strategies adapted over 2003 increased the likelihood of fishery sustainability. This claim was supported by results obtained from a survey conducted in February 2004 which showed that there was a significant ($p<0.005$) increase in biomass density in 2004 compared with 2003. The annual mean increased from 3.89 to 6.62 lb/min (sed = 0.52). The increase mean biomass density was mainly attributable to a significant ($p<0.001$, Wald statistic = 44.74) increase in Region 1 from 4.56 to 9.56 lb/min (sed = 0.68). Most importantly, information from the monitoring of catch and size of prawns during fishing operations indicated that a large recruitment pulse of small prawns (<20-30 mm CL) occurred in April 2004. The large recruitment pulse resulted in the implementation of spatial closures over segments of important grounds (e.g., the Gutter) through recommendations from the FMC (CAS). The strong recruitment pulse is most likely attributable to the protection spawners from October-November as the pulse matches the size of 'direct' recruits derived from spawning in November-December.

The analysis of November biomass trends and prawn spawning data which was required for the FMC committee meeting in November 2003 had to be completed within 6 hours, most of that time being spent collating and entering data due to a number of problems in the transfer of information (e.g., delays in sending data at the required time). The research undertaken demonstrates that the DSS developed for the fishery has the potential to increase profitability (value of catch - costs of fishing), as well as the sustainability of the fishery. The system can be largely improved by enhanced Oracle database systems and better harvest models, providing adequate support and cooperation is provided by industry.

7.6 Visualisation and animation of prawn movement in Spencer Gulf

Animation of prawn movement was tested using the ESRI ArcGIS Tracking analyst extension. SQL Plus scripts were written to group prawn tag recaptures by specified time intervals (e.g., 30, 60, 90 days) at liberty to allow detailed visualisation of temporal movement patterns.

Prawn recapture data, in the test example provided, include 5 244 validated tag returns, recaptured from commercial fishing and trawl surveys from June 1985 to November 1992. The distribution of time at liberty (i.e. days from release to capture) shows a marked skew due to intense fishing intensity and to the movement of prawns into fished areas (Figure 7.47). It is noted that there were 12 recaptures which were at liberty for over 660 days. Results show that there are more defined movement patterns when recaptures are plotted over short time intervals at liberty which are somewhat 'disguised' by a plot of total recaptures (Figure 7.48). When recapture data is plotted over discrete time intervals, movement patterns become more pronounced (Figure 7.49 to 7.55).

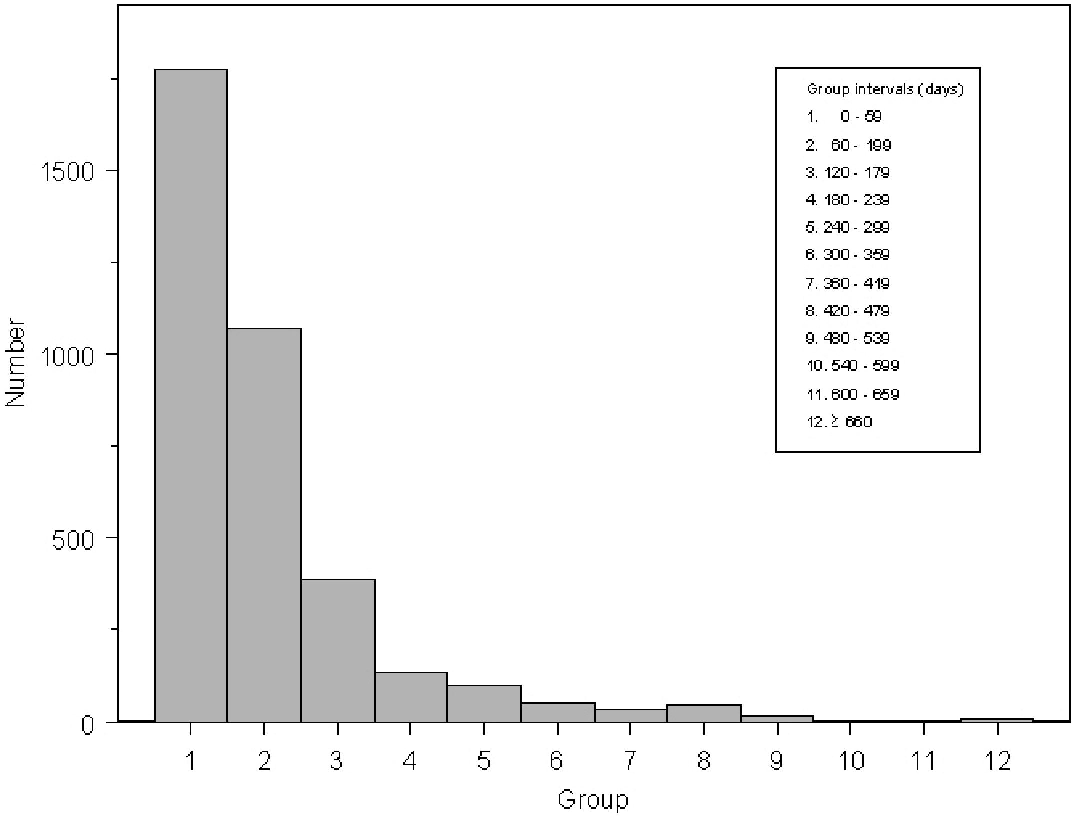


Figure 7.47: Histogram of time at liberty of released tags using 60 day intervals.

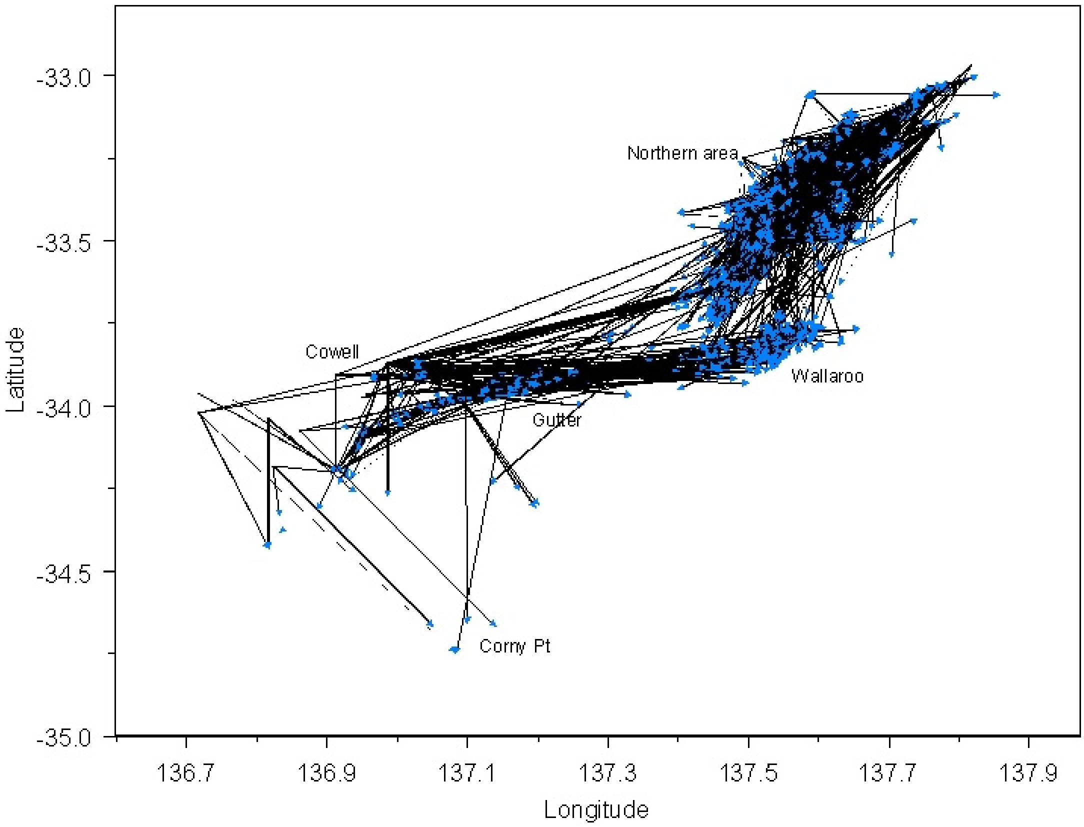


Figure 7.48: Prawn tag movement vectors in Spencer Gulf using 3,620 recaptures from June 1985 to November 1992.

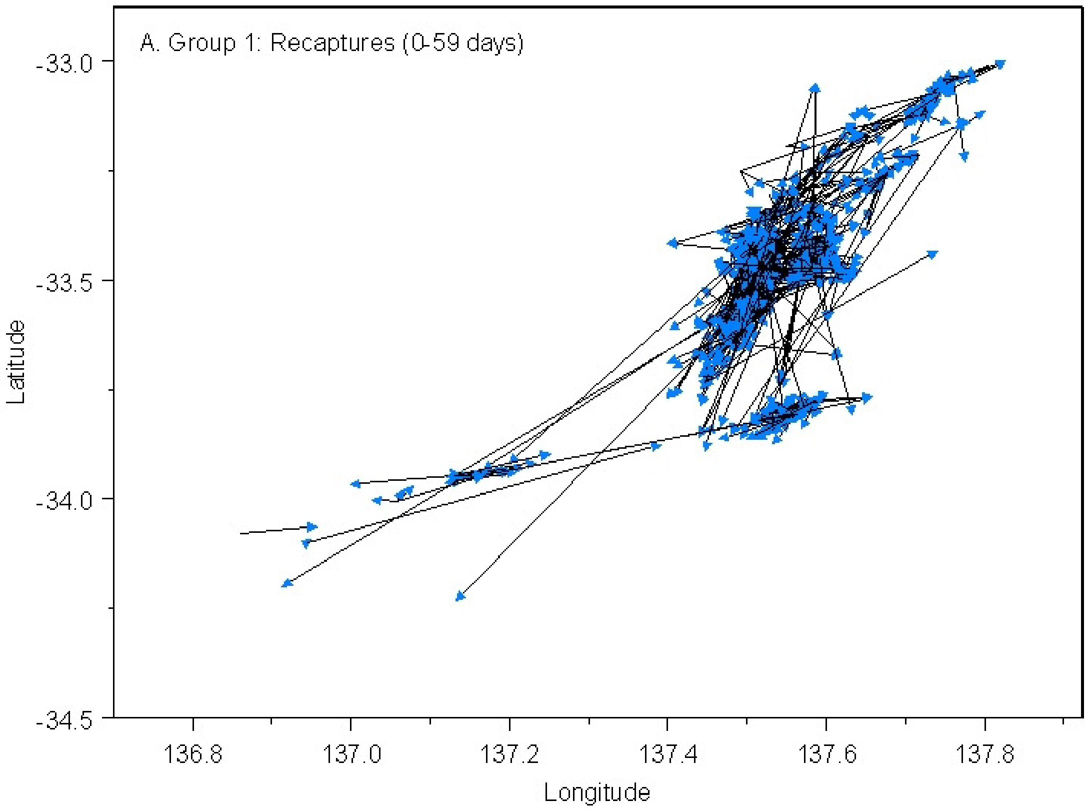


Figure 7.49: Prawn tag movement vectors in Spencer Gulf with a time at liberty interval of from 0-59 days.

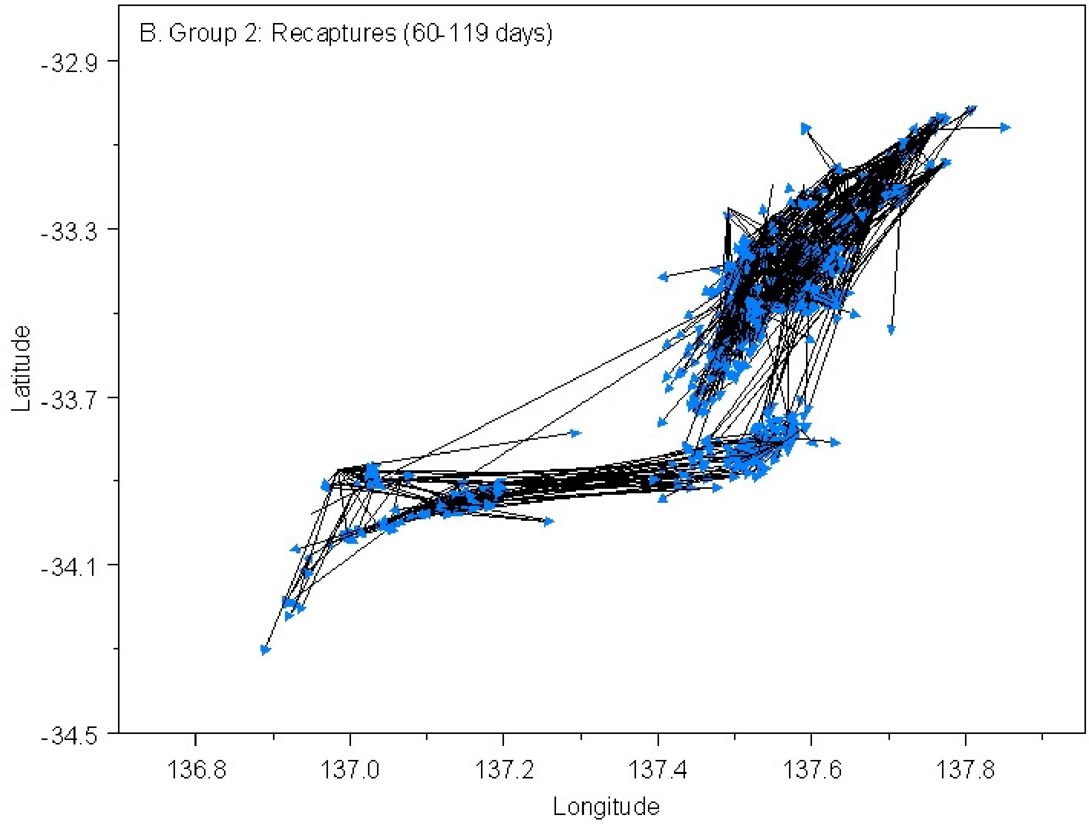


Figure 7.50: Prawn tag movement with a time at liberty interval of from 60-119 days.

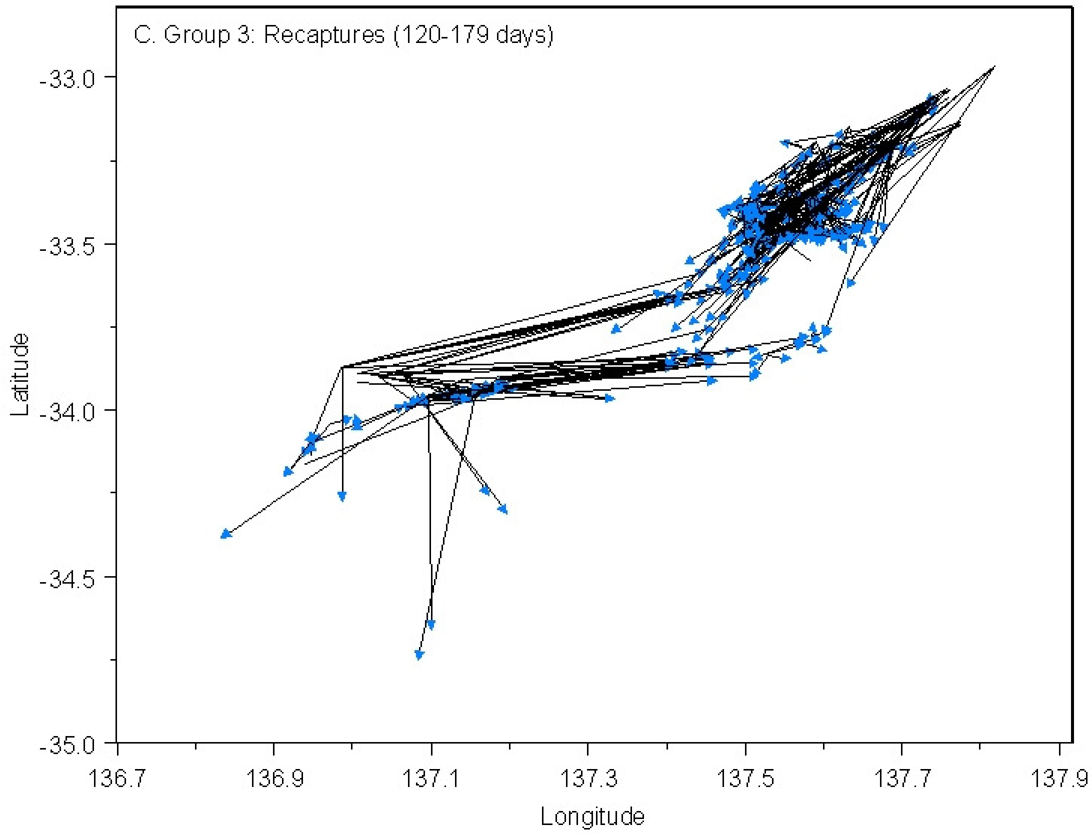


Figure 7.51: Prawn tag movement with a time at liberty interval of from 120-179 days.

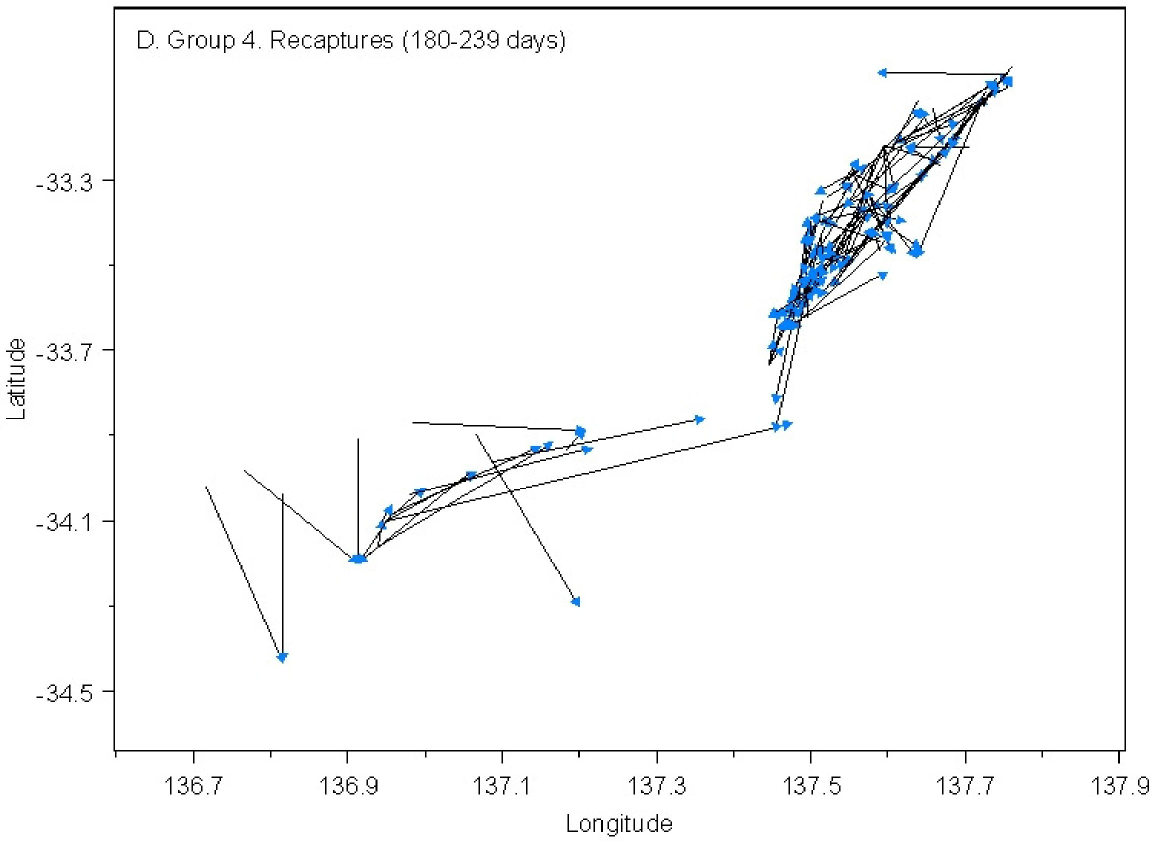


Figure 7.52: Prawn tag movement with a time at liberty interval of from 180-239 days.

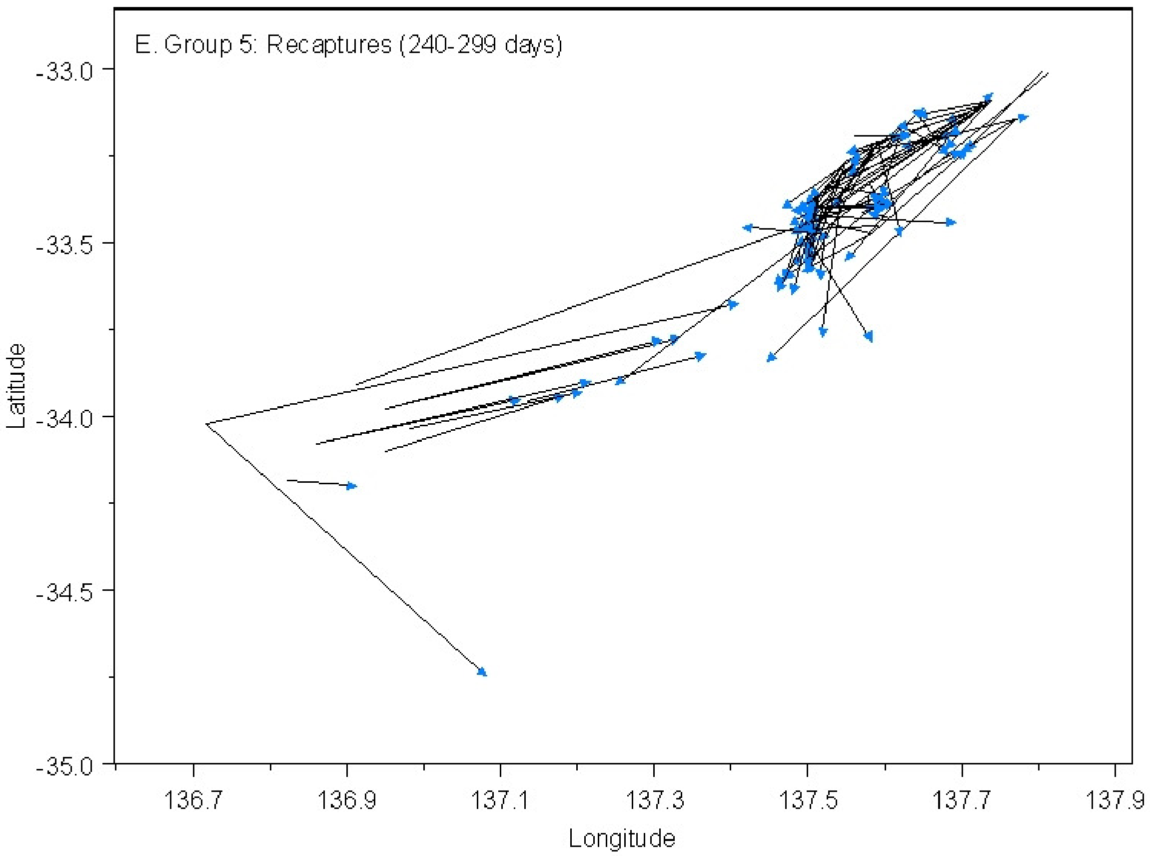


Figure 7.53: Prawn tag movement with a time at liberty interval of from 240-299 days.

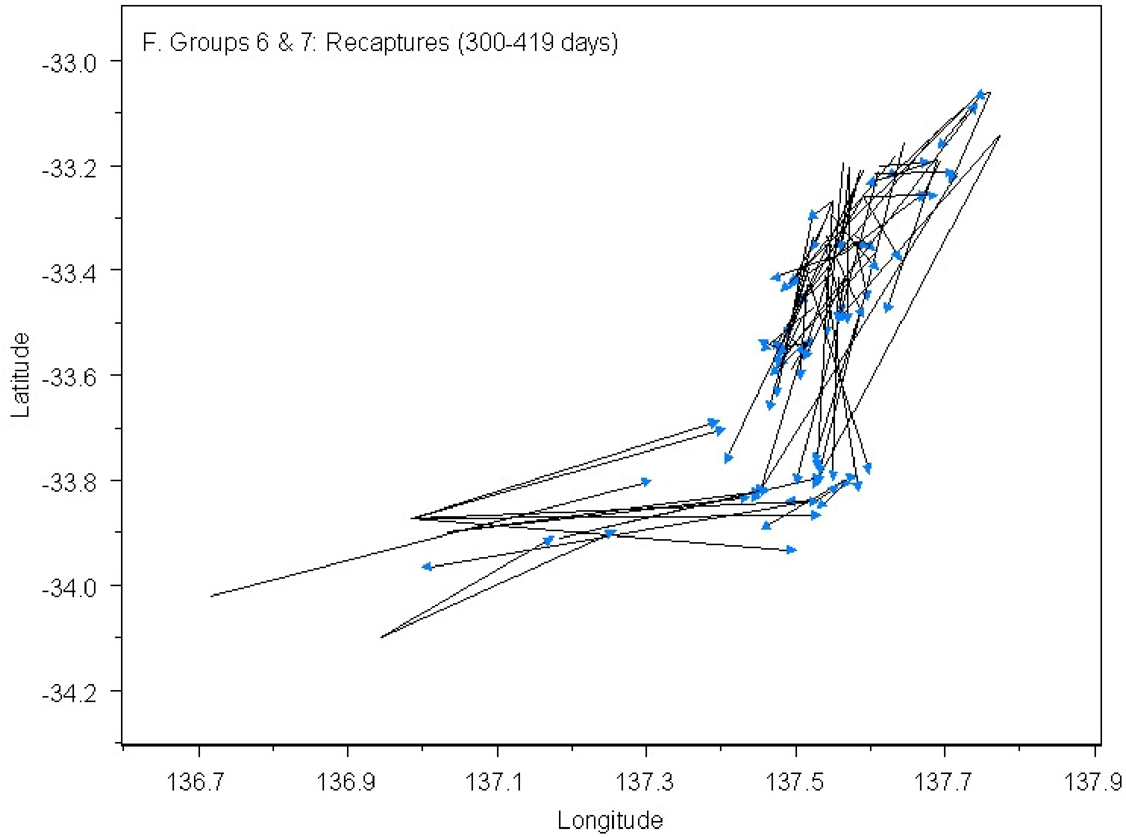


Figure 7.54: Prawn tag movement with a time at liberty interval of from 300-419 days.

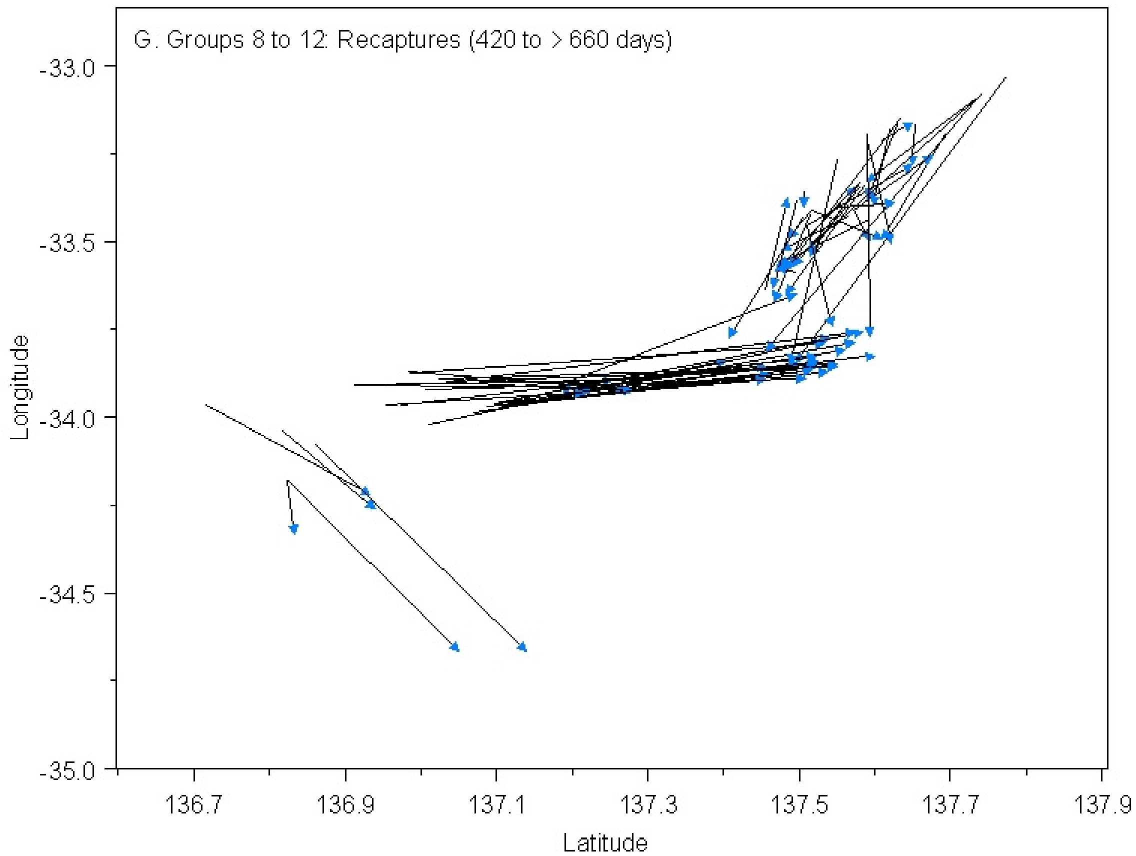


Figure 7.55: Prawn tag movement with a time at liberty of >420 days.

A prawn movement animation of Spencer Gulf tag recaptures was undertaken using 2-week time intervals which generated 212 frames, and saved in .avi format for replay using multi-media software (Figure 7.56). The animation sequences are being enhanced and will be posted on the spgprawn web site to provide a greater understanding of the fishery biology and promote the FRDC research.

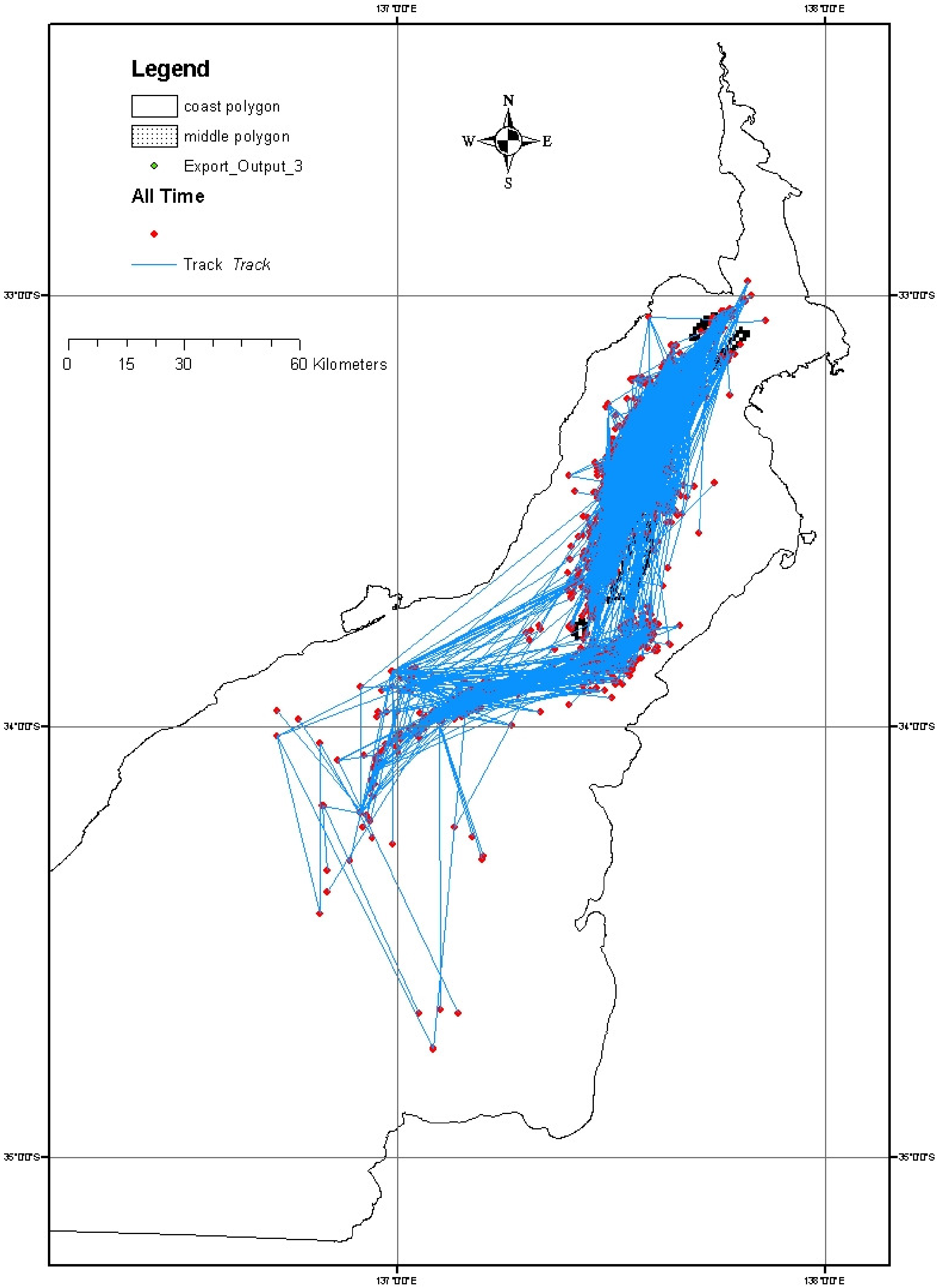


Figure 7.56: Animation profile (frame no. 212) of prawn tag movement in Spencer Gulf with a temporal sequence of 2 week intervals from June 1985-November 1992.

8 Spatial changes in prawn production and appraisal of the benefits of adaptive harvest strategies and spatial closures in Spencer Gulf

8.1 Influence of prawn dispersal and depletion patterns on stock assessment and on the development of harvest strategies

8.1.1 Background

An understanding of prawn dispersal and stock depletion patterns is required for stock assessment and for the development of harvest strategies in penaeid prawn fisheries. The aim of harvest strategies in Spencer Gulf is to maintain fishery sustainability, optimise the value of catch and "spread" the fleet. The "spread" of the fleet is influenced by the prawn biomass density distribution over the fishing area (fishing blocks), the area available and the trawl value. Trawl value ($/h) is a function of the catch and price structure of prawn size grades. High spatial depletion of grounds can result in pressure to "open" more grounds in successive periods although prawns are below the optimal size for harvesting.

Movement and aggregation of prawns into fished areas can result in biased estimates of fishing mortality and stock size. CPUE, the conventional gauge for evaluating the "health" of a fishery, can provide a misleading interpretation of stock size, as supported by the scholarly literature, (see Paloheimo and Dickie 1964, Ricker 1975, Gulland 1983, Hilborn and Walters 1992, Grecco and Overholtz 1990, Swain and Sinclair 1994, MacCall 1976, Winters and Wheeler 1985, Clark and Mangel 1978, Quinn and Deriso 1999, Seber 1982, Bannerot and Austin 1983, Richards and Schnute 1986, among others).

Most fisheries management agencies recognise that controls on fishing mortality rates (F) and catch are needed to prevent recruitment and growth overfishing. CPUE is an index of density, and stock size is a function of density, the area fished and spread (or dispersion) of the stock. Stock distribution can spatially contract due to fishing or environmental influences (e.g., ENSO events, see above). There are major problems in assessing prawn stocks using commercial data where there is no information on catch and effort in areas that are not fished. Furthermore, CPUE can provide misleading information on stock size due to the expansion of grounds within fished areas which can maintain high CPUE when the stock has declined. Furthermore, stock assessment can be biased by not incorporating historical changes in fishers targeting practice, which is influenced by price structure of different grades. It is frequently assumed that there is a proportional relationship between fishing mortality rate (F) and effective fishing effort (E), and often described as:

$$F = qE \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where the catchability coefficient (q), defined as the fraction of the stock removed per unit of fishing effort, is constant. When catchability (q) is constant, fishing mortality rates (F) can be controlled through constraints on effort, and stock (N) can be monitored by changes in commercial CPUE which is referred to as I, where:

$$I = qN \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

However, the concept of catchability is loosely defined in the fisheries modelling literature. Catchability incorporates an index of stock availability (vulnerability) which reflects variation in behavioural responses attributable to endogenous rhythms and environmental variation (e.g., water temperature, moonlight illumination, water clarity etc.). Hence, vulnerability can vary by day and by season in penaeid stocks. Excellent reviews of the effect of environmental variation on "catchability" or vulnerability (v) are provided in Dall *et al.* (1990), Penn 1984, Joll and Penn (1990), and Sluczanowski (1981). In most of the modelling literature, catchability (q) variations are attributed to changes in the fishing power (fishing performance) of vessels due to the vessels physical attributes (length, mass and main engine power), improvements in trawl gear efficiency (e.g., headline length, trawl board size, and spread of nets), adaptation of technology (e.g., GPS plotting hardware/software, communication systems) and learning. Vulnerability is frequently assumed to be constant and is confounded by variations in effective effort and natural mortality. Few penaeid fishery studies have included variations in catchability due to variations in prawn vulnerability (availability) attributable to endogenous rhythms and responses to the environment. Fishing patterns have changed in many Australian penaeid fisheries due to closures (daylight trawling, moon, spatial and seasonal closures) which would result in biased estimates of historical CPUE trends without accounting for catchability (q) and vulnerability (v) variations.

Equations (1) and (2) are simplifications of complex interrelationships which have multiple dimensions and present major problems in modelling fish stocks. The assumption of constant q requires testing and would vary according to a number of factors, including in response to:

- Seasonal changes in stock vulnerability (v) due to prawn behaviour.
- Amount of area fished
- Dispersal or distribution pattern of stock over the fishery area and degree of stock aggregation
- Differences in fleet behaviour (e.g., searching and learning) and targeting.
- Changes in the fishing performance (or fishing power) of vessels in the fleet.
- Management constraints (e.g., spatial and temporal closures).

Fishing success (tonnes or $ captured) of individual operators is directly related to their fishing techniques which endeavour to maintain low catchability (q) with highest CPUE or value ($/h) over each fishing day. This implies that CPUE would result in biased stock assessments in competitive fisheries like Spencer Gulf where aggregations and dynamic dispersal occur. Hence, there is a need to incorporate fishery-independent data (trawl survey and tagging) in the stock assessment process to reduce bias in parameter estimates. In Spencer Gulf, fishery-independent trawl surveys for stock assessment were set up in 1981 in realisation of the biases associated with using commercial catch and effort data as the sole tool for the assessment and management of the fishery, (Carrick 1982).

Paloheimo and Dickie (1964) were the first to show that q varies inversely with stock abundance (N) and the geographical area occupied by the stock. Paloheimo and Dickie argued that q declines as stock size increases because each unit of fishing effort removes a higher fraction of the available stock when the stock is less abundant and confined to a smaller geographical area. This results in CPUE having a curvilinear relation to stock abundance (N). Hence, the Paloheimo and Dickie hypothesis implies that raw CPUE data would largely overestimate stock size and underestimate fishing mortality rates at low stock levels.

It is surprising that few studies are reported in the literature on penaeid fisheries where catchability variations have been estimated. The estimation of catchability variations in fisheries where the spatial distribution of catches has contracted is of significance to management. When contraction of grounds occurs in a fishery, one would expect catchability (q) to be higher than before contraction resulting in raw CPUE over estimating stock size.

The main and most critical assumption about catchability (q) is that it does not vary with abundance, which is tested in this preliminary study. This is the first study conducted in an Australian penaeid fishery to test the Paloheimo and Dickie hypothesis using standardised commercial catch and effort data. When nominal effort is standardised for fishing power, temporal catchability (q) variations are expected to be correlated to changes in abundance, area, spatial spread, size composition, trawl value and vulnerability (availability) of the population.

Inverse relationships between catchability and population size and area have been widely observed in marine pelagic schooling fish (MacCall 1976, Pope 1980, Ultang 1980, Winters and Wheeler 1985, Csirke 1989) and demersal fisheries (Pope and Garrod 1975, Houghton and Flatman 1981, Rose and Leggett 1991, Grecco and Overholtz 1990, Swain and Sinclair 1994, Quinn and Deriso 1999). Surprisingly, there are few detailed accounts of the relationship between catchability (q) and abundance (N) in penaeid fisheries in the literature. Ricker (1975) pointed out: “Inconstant catchability is perhaps the greatest potential source of error in applying methods of estimation based on secular change in catch per unit of effort”.

Fishers are strongly pressured to maintain catch rates as abundance declines and, in cases where an “extension of grounds’ occurs, the CPUE may not decline and would result in biased stock estimates when a fishery is declining. Francis *et al*. (2001) point out that there are more cases in the fishery literature where catchability decreases with increasing stock (hyperstability) than where q decreases with reduced stock size (hyperdepletion). Hilborn and Walters (1992) provide an excellent review, with examples of problems associated with the use of CPUE in stock assessment where q is influenced by abundance, spatial spread of the stock and fisher behaviour. The objectives of the study are to:

(a) Determine the relationship between catchability (q) and stock size (N).
(b) Evaluate annual and spatial depletion of prawn stock by the fleet.
(c) Explain how movement and dispersal of prawns can influence q and F.
(d) Determine if searching and learning in the earlier part of the night results in an increase in CPUE.
(e) Demonstrate that intensive trawling homogenises spatial pattern.
(f) Demonstrate the benefits of closing the Wallaroo region to fishing from January to April.

The benefits of closures (f) can be gauged by the increase in fishery profitability, “spread” of the fleet, fishery sustainability (e.g., through increase in population fecundity, see below). The appraisal of closures (f) was undertaken as an adaptive fishery experiment using both fishery-independent and commercial catch and effort data.

The main catchability (q) model tested is that proposed by Ultang (1980) which is a power function defined as:

$$q = aN^b \quad \text{..(3)}$$

Where a and b are constants. If b is significantly <0, then CPUE is a biased estimator of abundance when conventional catch-equation theory (constant q) is applied to stock assessments. Other catchability models have been proposed including those of Richards & Schnute (1986), Hilborn and Walters (1992, p.144), Bannerot and Austin 1983, Quinn & Deriso (1999, pp 28-29), among others.

The research will demonstrate evidence of a negative relationship between prawn stock size and CPUE in the Spencer Gulf prawn fishery, which can be considered as a depensatory density-dependent process. Hence, there are important management implications. That is, the use of CPUE as a gauge for stock size can result in an overestimate of the stock size.

Fisher searching, learning and handling time have been shown to influence fishery CPUE in aggregated stocks, (Clark and Mangel 1978). Handling time has no influence on CPUE or catchability in the Spencer Gulf fishery as vessels have large brine and freezer space to hold catch and hoppers for fast sorting. Catch and effort data was analysed to determine whether catch rates increase through the night on the assumption that learning in the earlier parts of the night result in increased catch rates later. The null hypothesis to test is whether rates would increase with increasing shot numbers over each night. Searching and learning in the earlier part of the night have been reported to result in an increase in catch rates towards the latter part of trawl operations as reported in the Gulf St Vincent prawn fishery (Xiao 2004).

8.1.2 Methods

5.12.1 Fishing mortality and depletion

Fisher daily catch and effort data from 1988 to 2001 for each fishing period from February to April was assembled and catch data cumulated by fishing day for blocks and assemblages of blocks. Data from the Wallaroo (blocks 37 & 38 and 40-50) and Middle Bank (blocks 35, 39, 36 & 31) regions (Figure 8.1) was used to study fishery depletion using the Leslie method.

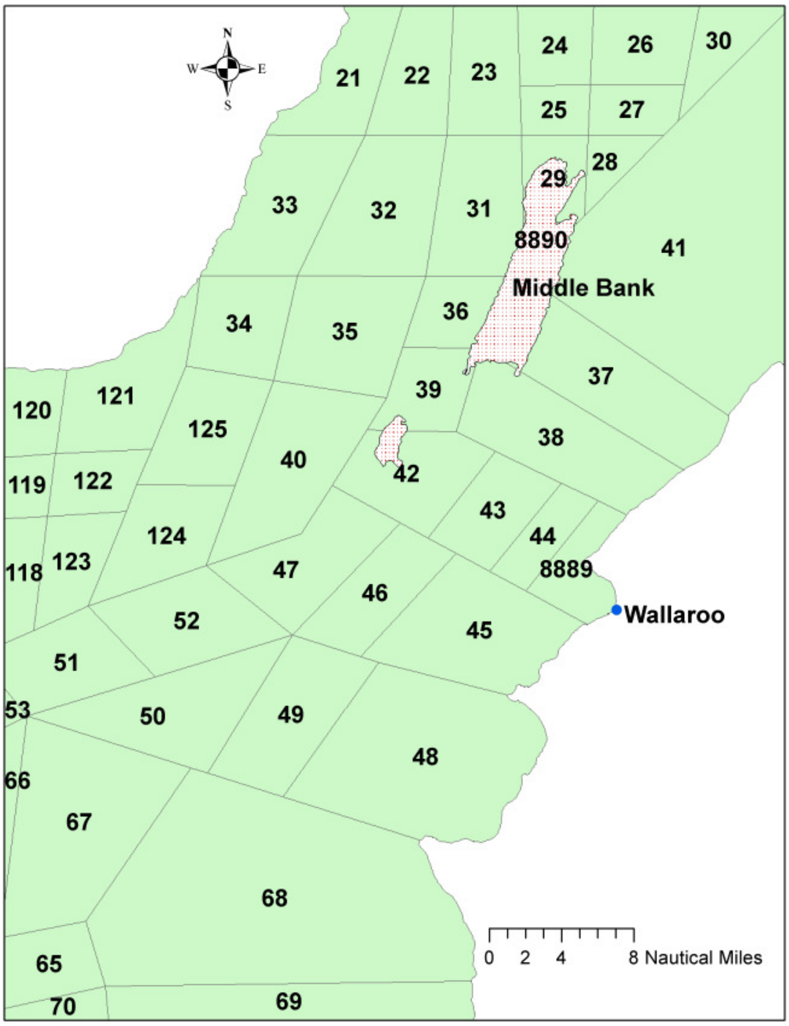


Figure 8.1: Geographical location of Wallaroo and Middle Bank fishing blocks.

Daily instantaneous fishing mortalities (F) were based on CPUE or biomass density (kg/h) as background research has shown negligible variation between numeric and ponderal mortality estimates at the small spatial and temporal scales used in the analyses. Mortalities (biomass density decay) were estimated for each fishing block in the Wallaroo and Middle Bank region using Poisson regression with CPUE (kg/h) regressed on fishing day within each fishing block for the period February/March to May over each year from 1988-2001. Due to report size constraints, only case examples that are representative and based on 1990, 1991, 1997 and 1998 (4 years) harvesting schedules are presented.

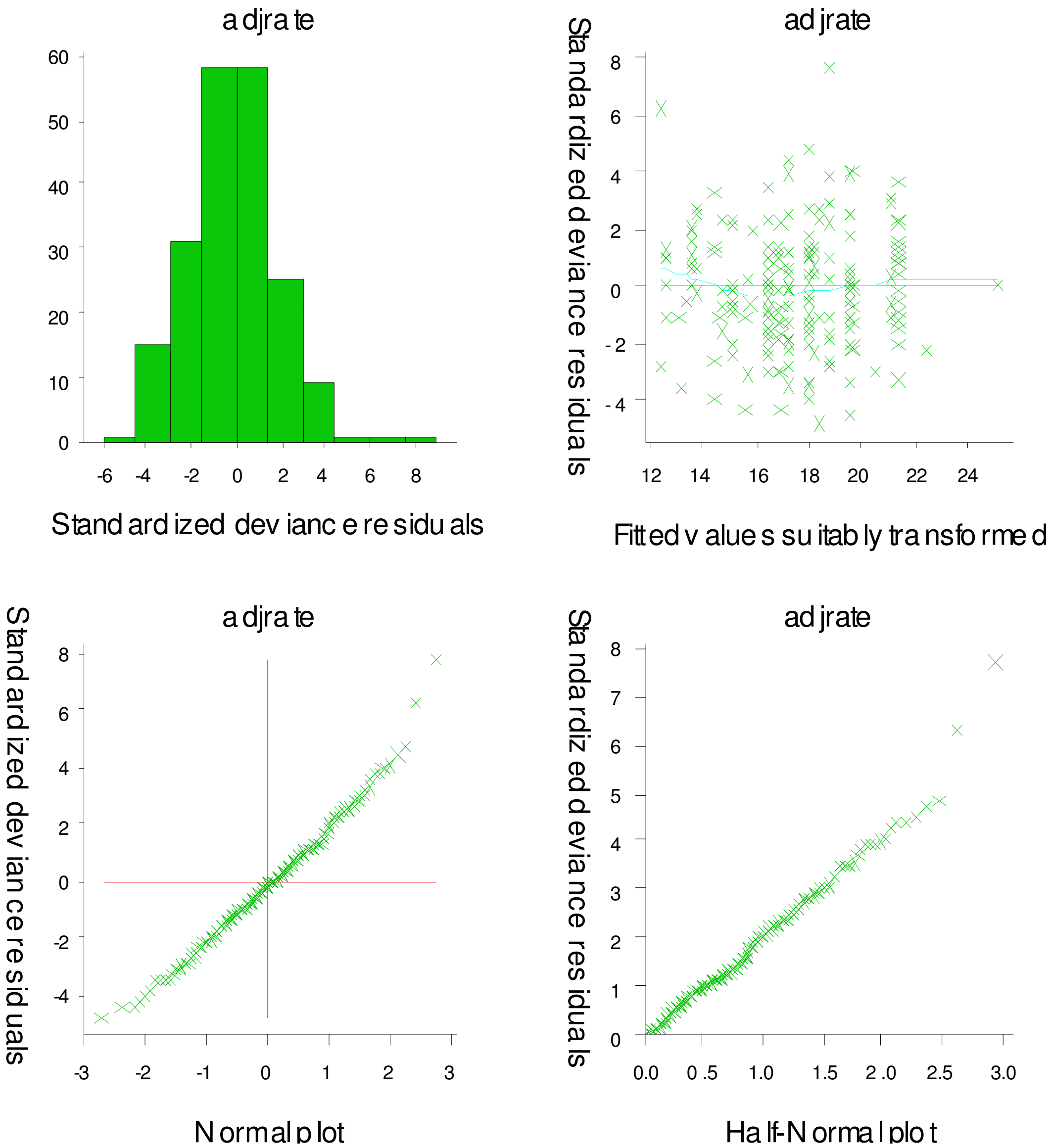


Figure 8.2: Residual distribution from Poisson regression of CPUE (adjrate) on Block/day no, February/March 1998, Wallaroo.

The Poisson GLM (or log-linear regression) models used to determine depletion were

(a) Fishing Block. CPUE = constant + block + fishing day.block or in Genstat terminology block/day

(b) Pooled blocks for areas (Wallaroo or Middle Bank). CPUE = constant + day no

The analysis used all vessels in the fleet as sampling units for each day. The Poisson model was used as background work showed that log-linear modelling using the log link function with the dispersion parameter set at 1 provides best fit to Spencer Gulf commercial catch and effort data, (see McCullagh and Nelder 1989). Quinn & Deriso (1999, p.30) point out that "regardless of the relationship between CPUE and abundance, it is important to understand the underlying statistical distribution of CPUE data". All regression residual fits using the log linear regression had satisfactory fit to the data and an example is provided on the methods used to examine fits using residual plots for February/March 1990 and April/May 1998 (Figure 8.2 and Figure 8.3)

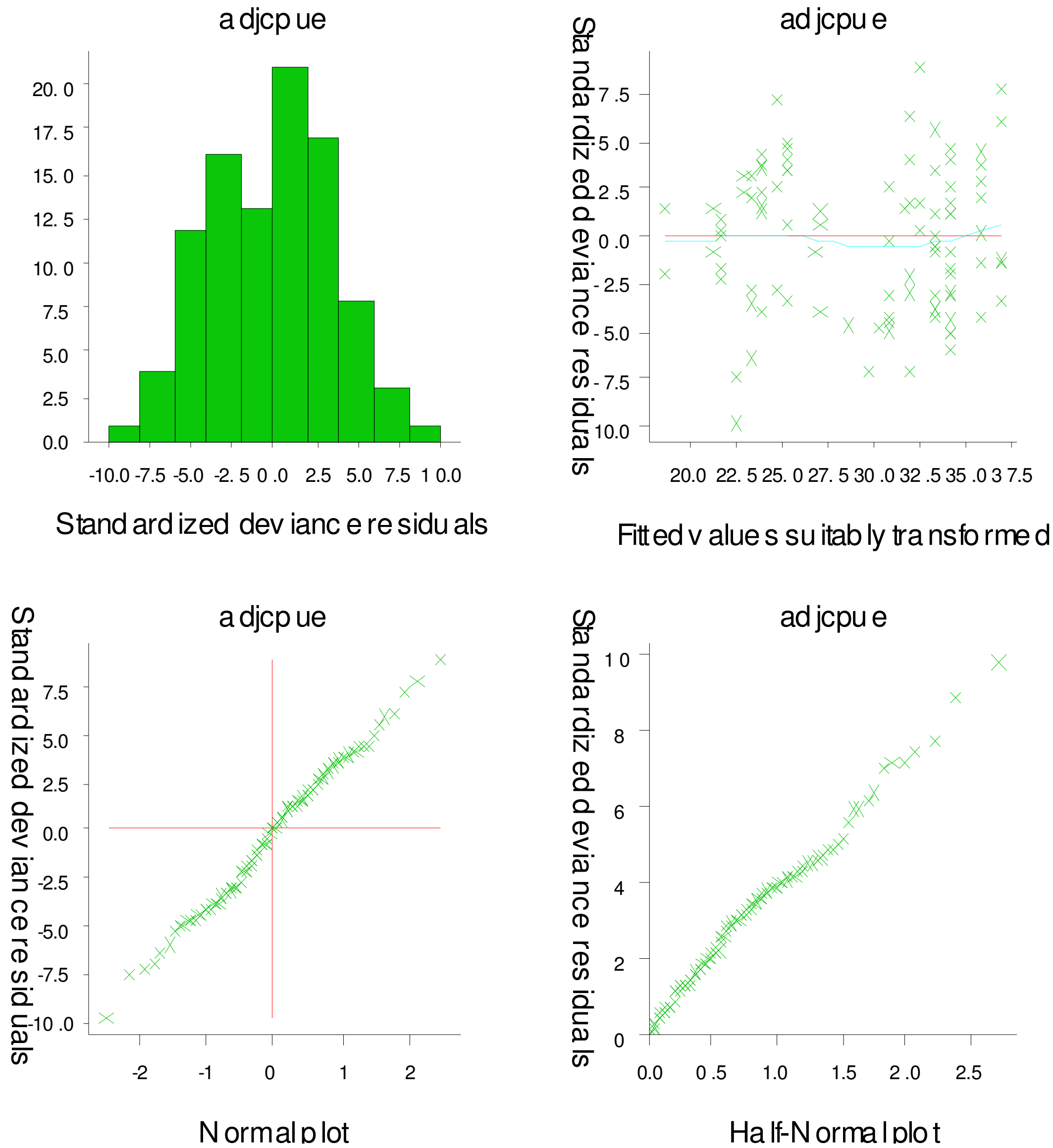


Figure 8.3: Residual distribution from Poisson regression of CPUE (adjcpue) on Block/day no, April 1998, Wallaroo and Middle Bank

Trellis plots were made to visualise depletion patterns with exponential and loess regression models fitted to data. Additionally, the SPLUS trellis panels provide visual indication of the spatial concentration of effort and distribution of CPUE over each fishing day for different regions in the Gulf. For example, in the February/March 1990 fishing period, trawl effort at

Wallaroo was most concentrated at Block 43 with catches taken from 9 blocks, (c.f. April 1998). Block depletion rates (F values) were incorporated in the trellis graphics where there were >3 data points.

The Leslie method is a simple linear regression of CPUE on accumulated catch from the commencement of fishing (day 0) to the end of a harvesting sequence (day n) (see Hilborn & Walters 1992). The Leslie method is based on a number of assumptions including:

1. The catchability (q) of the fished population is constant among individuals and over the period of investigation.
2. Fishing effort is uniformly distributed over the area occupied by the stock.
3. The fished population is closed. That is, no emigration, immigration and no natural mortality.
4. The fishing performance (fishing power) does not change over the study period.

The main problem with the Leslie method is the assumption of a linear relation between CPUE and the density of stock fished. The method has been shown to have major problems for the assessment of crab and lobster populations by potting (Miller and Mohn 1993) and researchers have developed "open" population models to account for (3) (Quinn 1987). The Leslie method has been shown to underestimate crab and lobster population densities in short-term "fish-downs".

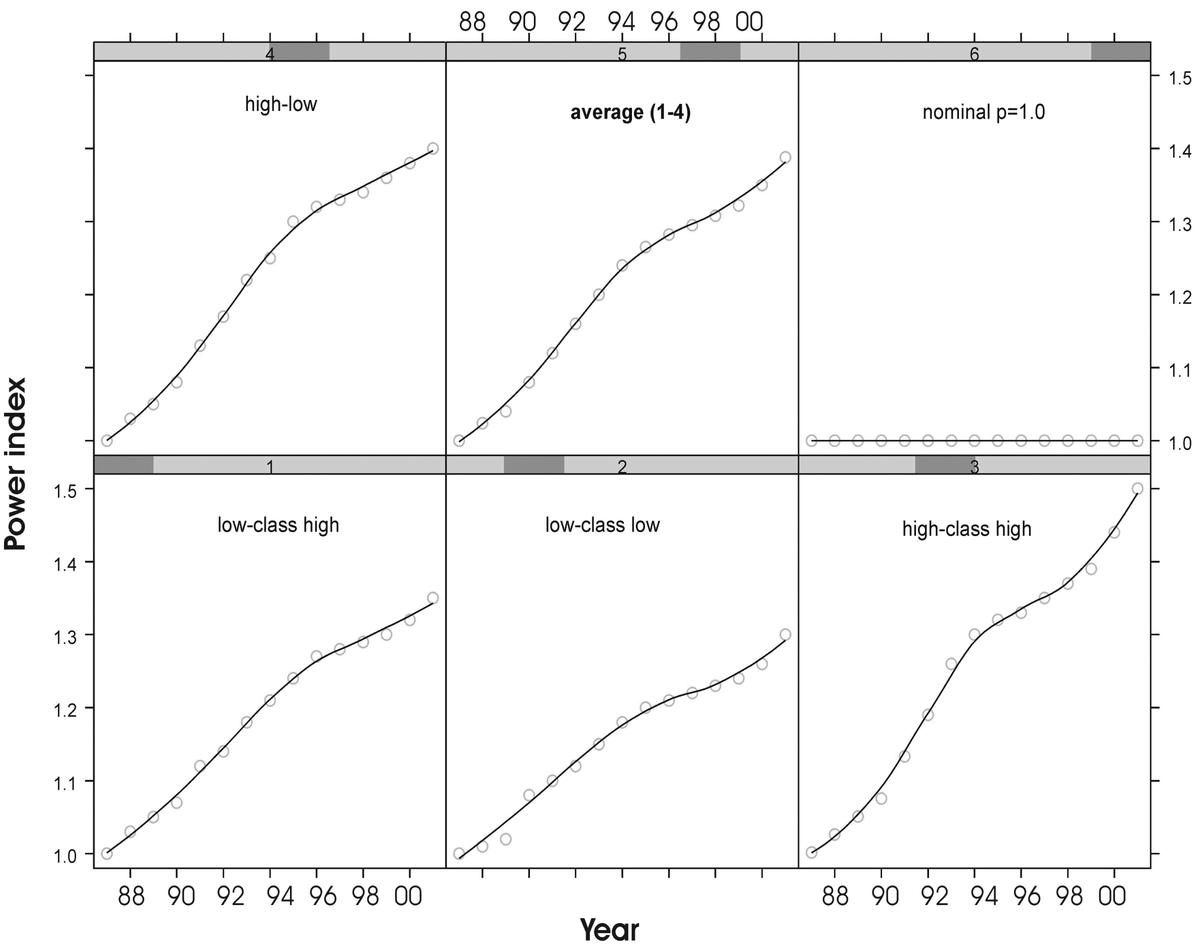


Figure 8.4: Model of comparison of fishing power changes in the Spencer Gulf prawn fishery from 1987 to 2001 using different annual increments for the effects of

increases in vessel size, learning and adaptation of technology fitted to loess regression models for 5 classes of increase. Adapted from Carrick (unpublished)

In this study catchability (q), referred to in (1), needs clarification. The vulnerability parameter is set at 1 as background work has shown that there is negligible variation over the periods used in the analyses, and natural mortality (M) would be small (approx. 0.002/day) and constant between regions as depletion was based on day within periods. Raw commercial effort data was standardised to effective effort by multiplying nominal effort (hours) by fishing power estimates. Annual fishing power (or fishing performance) estimates of the fleet were obtained from GLM modelling using indexed CPUE then adding incremental increases expected to be associated with learning and adaptation of technology (GPS plotters and software, tracking and communication systems, etc) and increases in vessel length and engine size. The average fishing power model (panel 5) was used to standardise effort (Figure 8.4). The average fishing power model applied predicts that there was approximately 38% increase in fishing power from 1987 to 2002 with 1987 indexed to 1.

The main violation to the assumptions of the Leslie method applied in the study relates to the confounding of CPUE through movement dispersal into the fished area on a closed population assumption. The main analytical methods used in the study were:

(a) Visualisation of changes in CPUE over fishing days for each block, assemblages of blocks and regions.
(b) Derivation of daily fishing mortality rates using Poisson regression for whole regions (Wallaroo, Middle Bank) and smaller spatial regions (fishing blocks within regions).
(c) Linear regression of standardised CPUE on cumulated catch to estimate the parameters q (catchability or the regression slope) and the intercept used to estimate stock size (N) as N = intercept/q. Catch data was cumulated by day over region (and blocks) with effort standardised by fishing power using estimates obtained from background study of individual vessel fishing power changes of the fleet (unpublished).

The data sets consisted of >3 million records of commercial catch and effort trawl shot data. There were errors in data entry and problems associated with deciphering fishermen's writing but they were corrected for this study. Catch and effort shot data over a night for each vessel was pooled for estimates of daily instantaneous mortality rates. Genstat and Splus were used jointly to assemble data files (e.g., cumulated catch), visualise data and obtain estimates of regression parameters (F, q and N).

A preliminary analysis of the influence of the area of fishing blocks (square nautical miles) on catchability (q) was tested using data on catchability estimates and fishing block area (square nautical miles) from 1996-97 with data restricted to December, March and April to mimimise seasonal vulnerability changes. Data was subjected to linear and nonlinear regression to determine whether catchability decreases with an increase in the area of fishing blocks, (see Winters and Wheeler 1885).

To test the hypothesis that 'learning' through a fishing night results in increased catch rates as the night progresses required testing whether CPUE increases (linearly or exponentially) with increasing shot number. CPUE data from April and May 2001 was used to test the hypothesis with trawl shot duration constrained to <65 minutes over each night for all vessels. Data was plotted using a loess smoother (DF = 2, span = 1) to illustrate daily trends in CPUE. Data was subjected to linear, Poisson and nonlinear regression models to determine whether the catch rate increases as a function of trawl shot number. Trawl fishing in Spencer Gulf only takes place at night, usually beginning at sunset and terminating at sunrise with most trawl shots being <65 minutes in duration. The mean trawl shot duration over the two periods (April and May) used for the study of the relationship between shot number and catch rates ranged from 42-45 minutes.

8.1.3 Fishing mortality and depletion

1990

Fishing at Wallaroo began in February for 7 nights. The fishing mortality for all blocks was – 0.168 ± 0.005 and was significant ($p<0.001$, $t = 31.23$), (Figure 8.5). Block 43 was most intensively fished with a daily instantaneous fishing mortality (F) rate of – 0.175 per day or approximately 17.5% reduction in CPUE over each day.

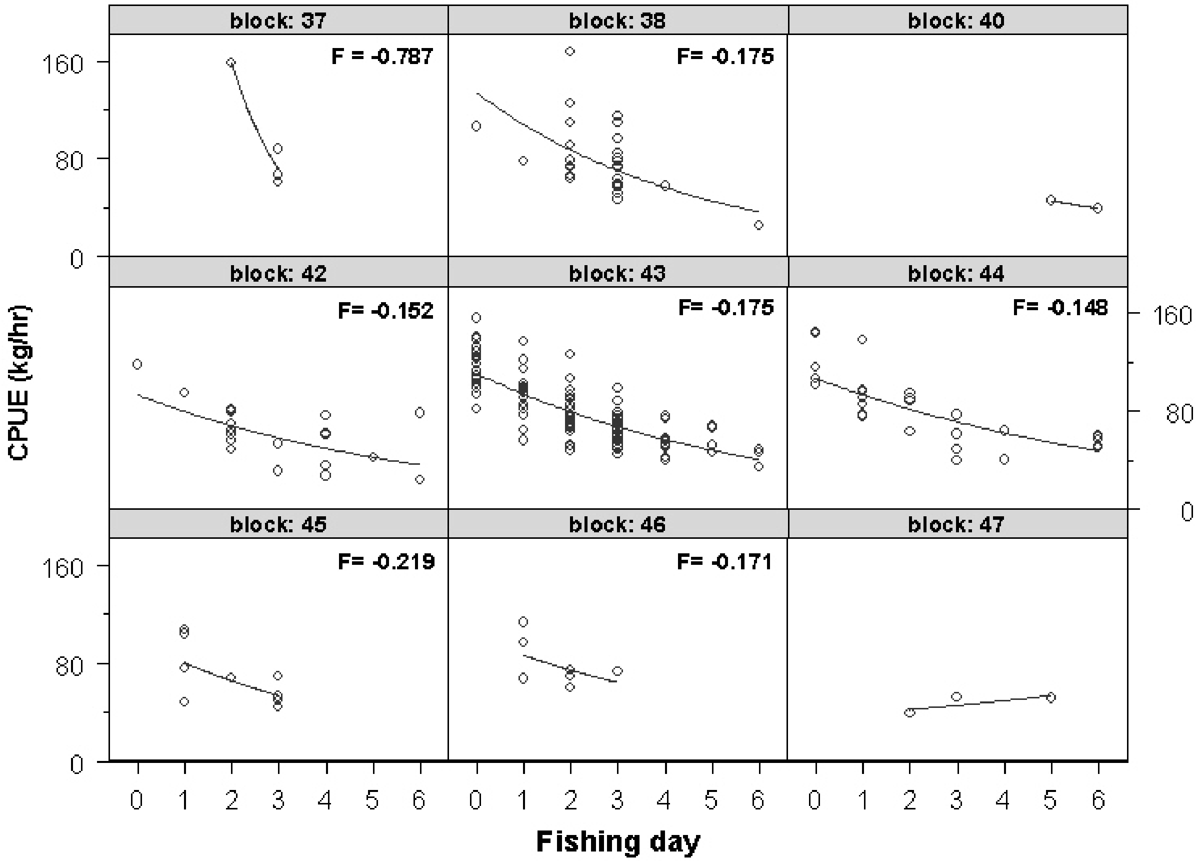


Figure 8.5: CPUE (kg/h) depletion over Wallaroo fishing blocks, February/March 1990.

Fishing continued at Wallaroo over March/April for 12 nights (Figure 8.6). The regression constant declined from 107.1 ± 2.58 in February/March to 65.5 ± 1.65 in March/April which was significant (p<0.005) reflecting depletion in biomass density in the February/March fishing period. The instantaneous fishing mortality pooling all blocks for a regional estimate was -0.074 ± 0.002 /day or about 7.4 % per day.

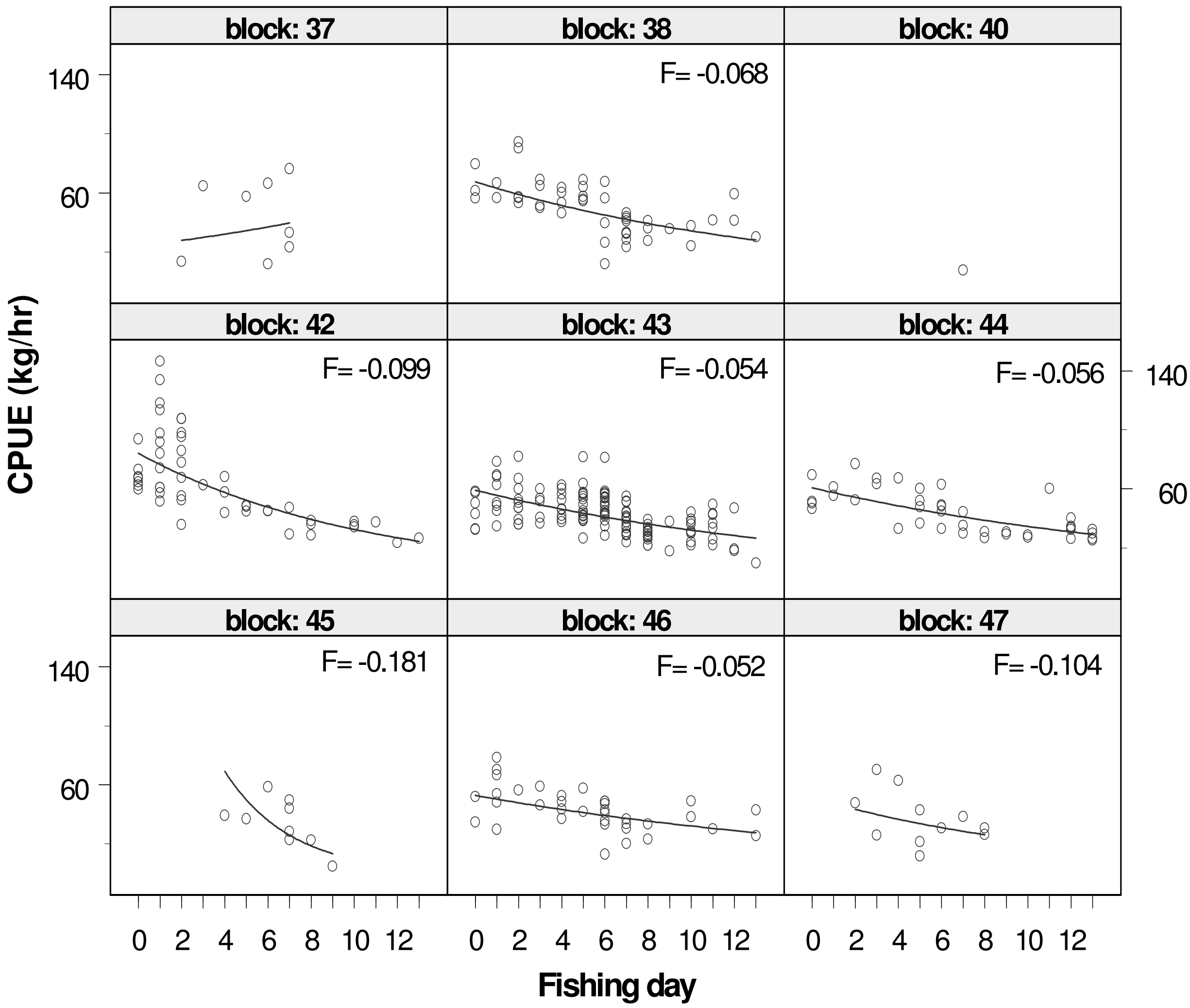


Figure 8.6: CPUE (kg/h) deletion over Wallaroo and Middle Bank fishing blocks from in March/April, 1990.

In April/May 1990, fishing took place in the Wallaroo and Middle Bank regions from mid April for 12 nights, with the Middle Bank region opened on the 5th fishing day (Figure 8.7). High fishing mortality was apparent in the Middle Bank (blocks 36 & 39) due to prawn aggregation and relatively small fishing area. The biomass density of prawns at the larger Wallaroo region (blocks 37, 38 and 40-47) was relatively low as the population had been fished down in earlier fishing periods (February/March and in March/April 1990) resulting in depletion values less than 7% per day compared with 35-50% per day in the Middle Bank region.

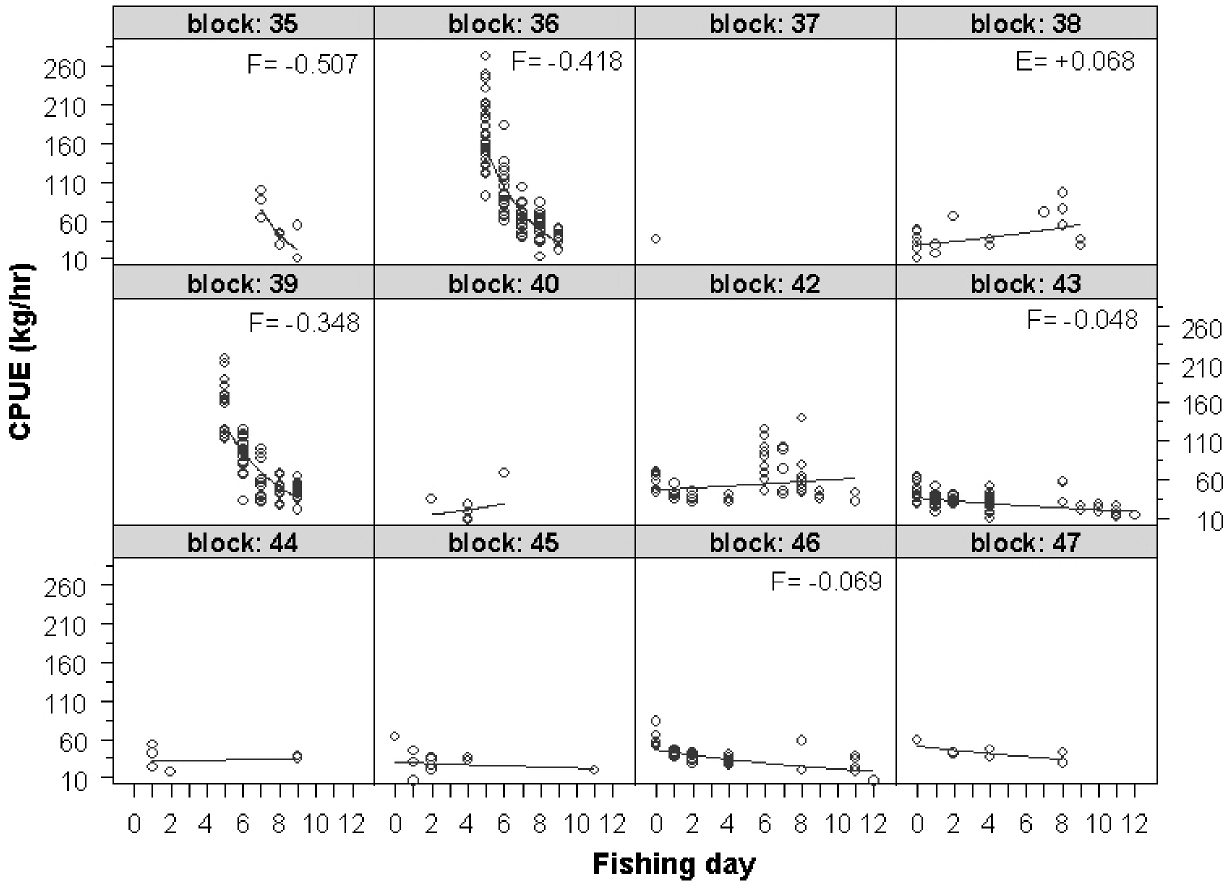


Figure 8.7: CPUE (kg/h) depletion over Wallaroo and Middle Bank fishing blocks from in April/May, 1990.

1991

Trawling began at Wallaroo on March 9th for 13 nights. Total mortality over blocks was -0.087 which may be underestimated if prawns were continuously moving into and dispersing through the region (Figure 8.8). On fishing day 5, there was an increase in catch rates at Block 42, 38 and 43 which was attributed to the movement of smaller prawns into the area from the north as verified by monitoring changes in prawn composition on vessels and tag recaptures. CPUE declined at rates ranging from 7-25% per day over blocks with the most intensively fished block (43) having a rate of - 0.084/day, which was relatively low. Prawns captured at blocks 38 and 43 were "mixed" in size composition and not of optimal target size (personal observation).

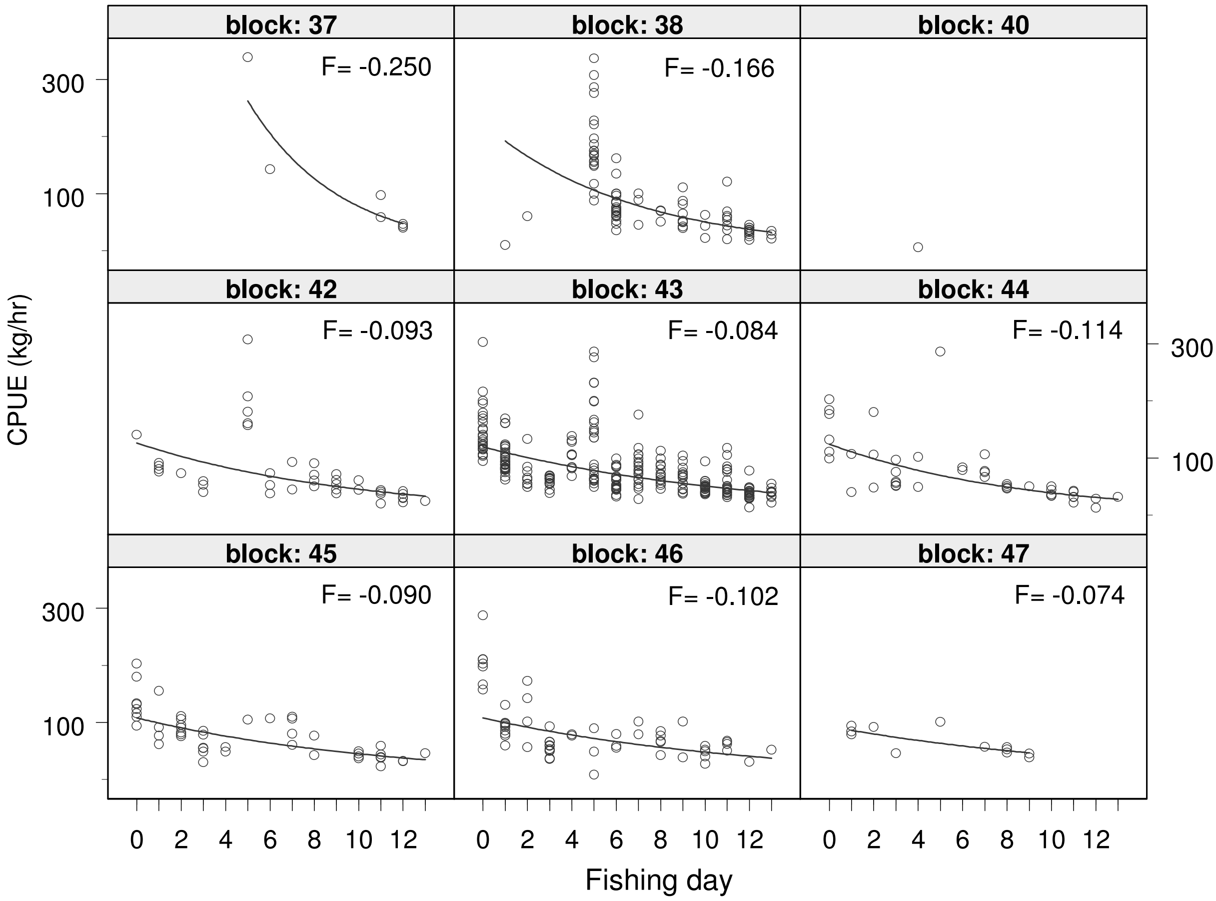


Figure 8.8: CPUE (kg/h) depletion over Wallaroo fishing blocks in March 1991.

Fishing recommenced in April for 11 nights. The population was reduced by fishing in March as reflected by the relatively low catch rates in April compared with March (Figure 8.9). The fleet spread to the southern area due to relatively low economic gain (or catch rates) at Wallaroo with the Middle Bank area closed to allow prawns to grow to larger size. The pooled block fishing mortality for Wallaroo was -0.087/day, about a 9% reduction in CPUE per day. The harvesting strategy could have been 'optimised' if no fishing occurred at Wallaroo in March or by directing greater effort away from the area to larger prawns in the southern region of the Gulf over the fishing period.

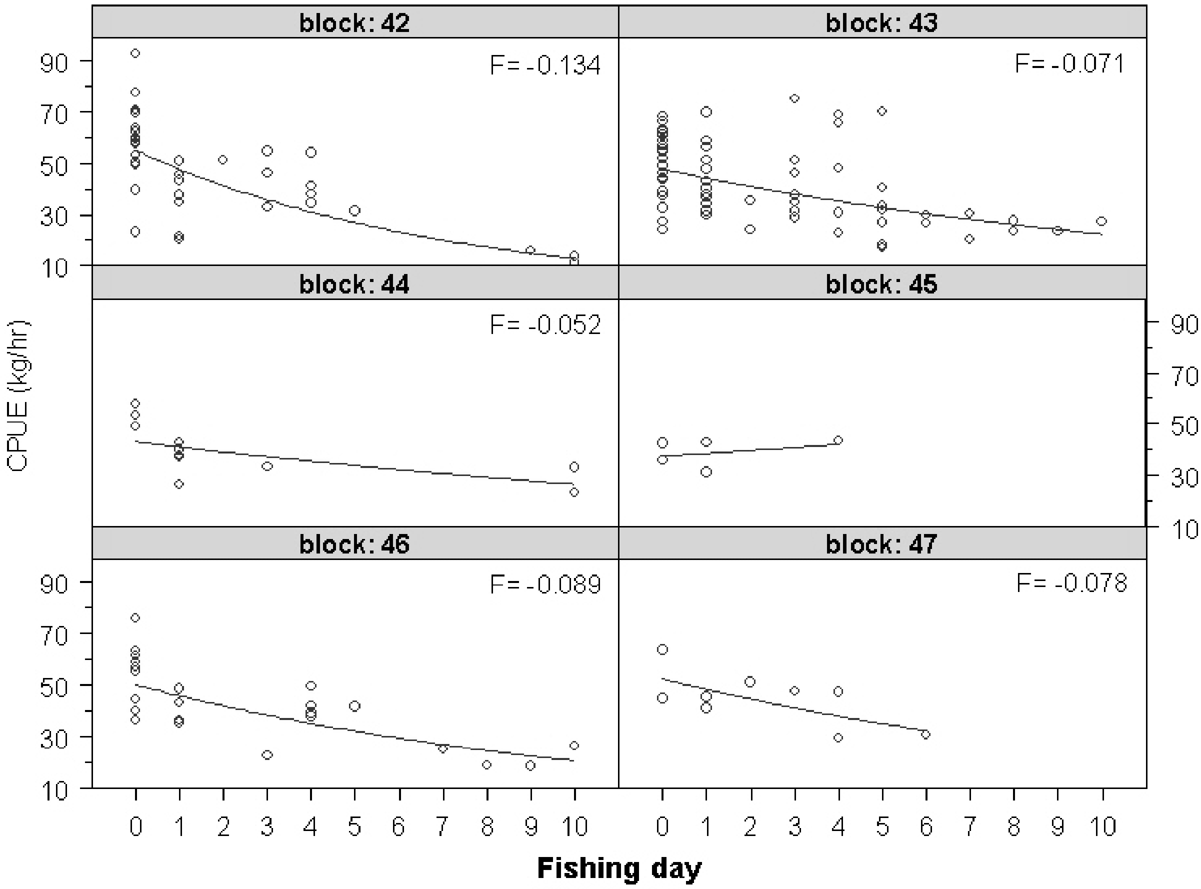


Figure 8.9: CPUE (kg/h) depletion over Wallaroo fishing blocks in April 1991.

1997

Fishing at Wallaroo began on March 4th for 11 nights despite recommendation to close the region or limit fishing to 3 nights. Here, CPUE data was fitted to a loess regression as exponential depletion was less evident (Figure 8.10). There was no strong evidence of depletion with relatively low fishing mortality rates, especially at the most intensively fished block (43). The pooled (block) depletion rate was low (- 0.007/day). As in 1991, catch rates were maintained by movement dispersal into the region from the north (e.g., Middle Bank) with daily monitoring indicating that the size composition of prawns captured was below optimum harvest size with a decrease in size from day 6.

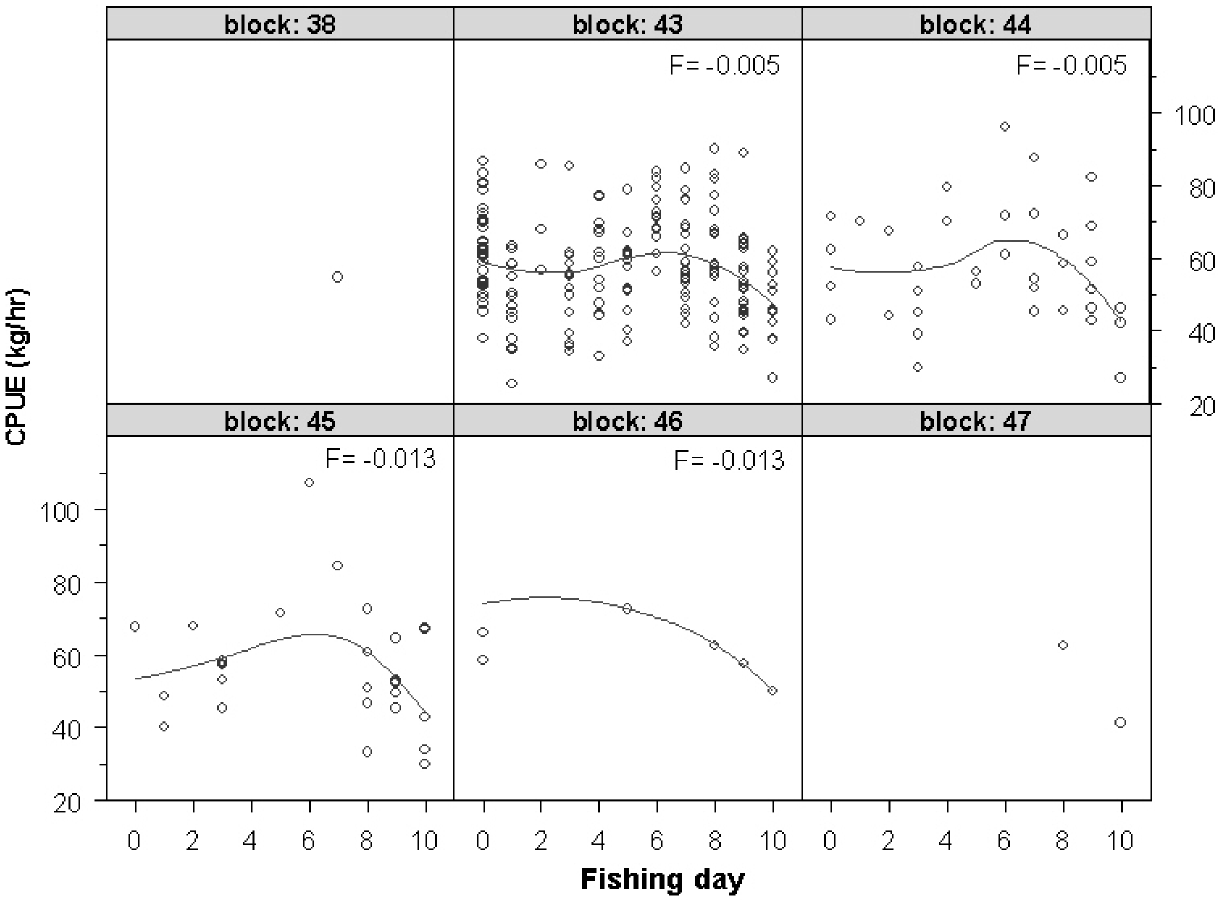


Figure 8.10: CPUE (kg/h) depletion by fishing day in March 1997 over Wallaroo fishing blocks.

Fishing recommenced on the April 7th at the Wallaroo region for 9 nights, with fishing concentrated at block 43 (Figure 8.11). There was a large increase (300%) in CPUE from March to April with the fleet reducing CPUE by about 22% per day. There was no indication of dispersal into the region through the fishing period as reflected by the steep decline in block catch rates, especially at block 43 where effort was most aggregated. The large increase in CPUE in April compared with March could only occur by movement dispersal over the interval from the termination of fishing in March to the commencement in April (i.e. moon closure). No fishing took place in the Northern region in April 1997 as prawns did not reach harvest size. The fleet concentrated fishing operations at Wallaroo and the southern grounds.

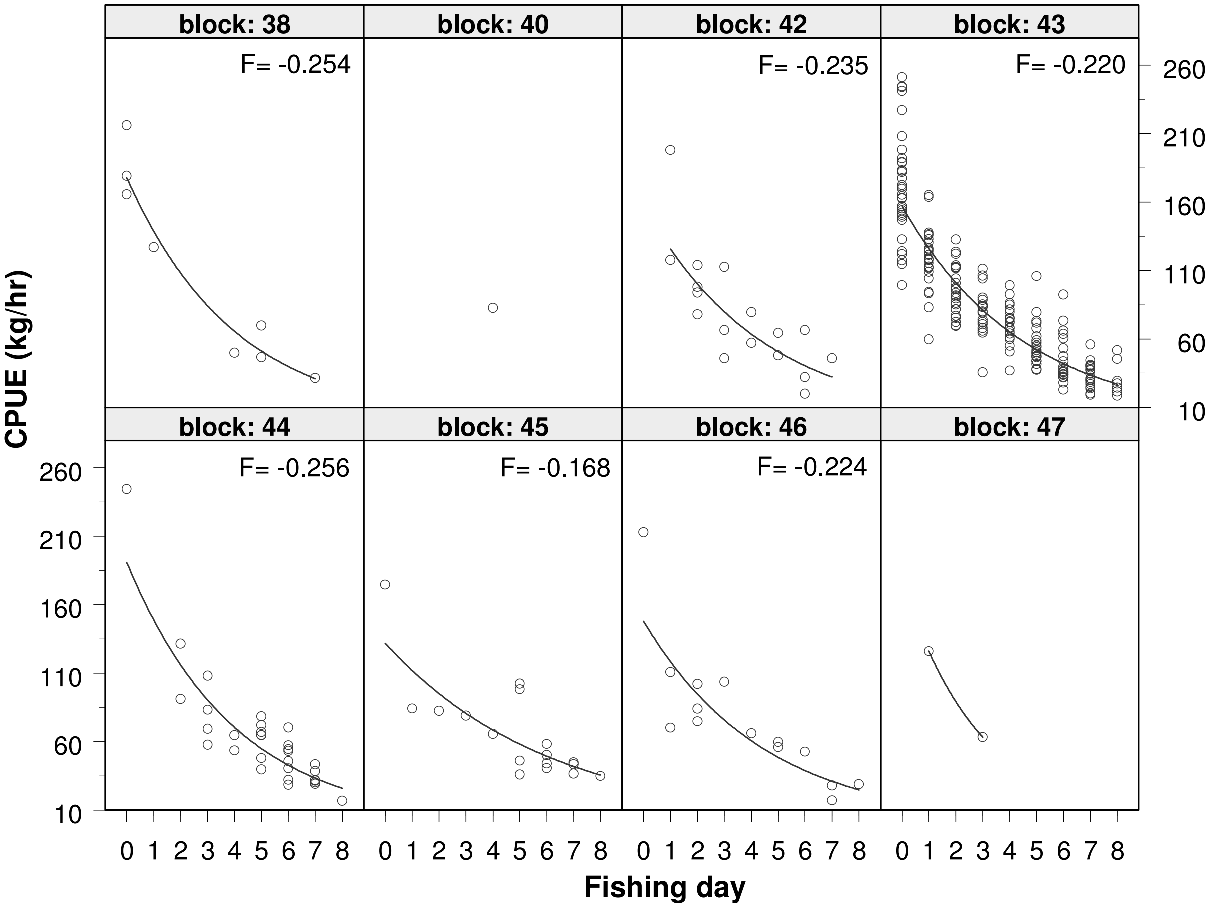


Figure 8.11: CPUE (kg/h) depletion by day in April 1997 over Wallaroo fishing blocks.

Fishing recommenced on the 1st of May at Wallaroo (blocks 38, 42, 43, 44, 45 & 47) with the northern area (blocks 23, 29, 31, 35, 36 & 39) opened 3 days later (Figure 8.12). Fishing intensity was highest at block 31 where a prawn aggregation occurred with some vessels recording CPUE rates >1000 kg/h. The pooled mortality estimate for the northern area was -0.407/day while the Wallaroo value was -0.061/day. That is, the fleet reduced the biomass density by about 41% each day in the northern area and by 6% a day at Wallaroo. The results indicate that prawn aggregation in small areas results in high fishing mortalities, (e.g., block 31).

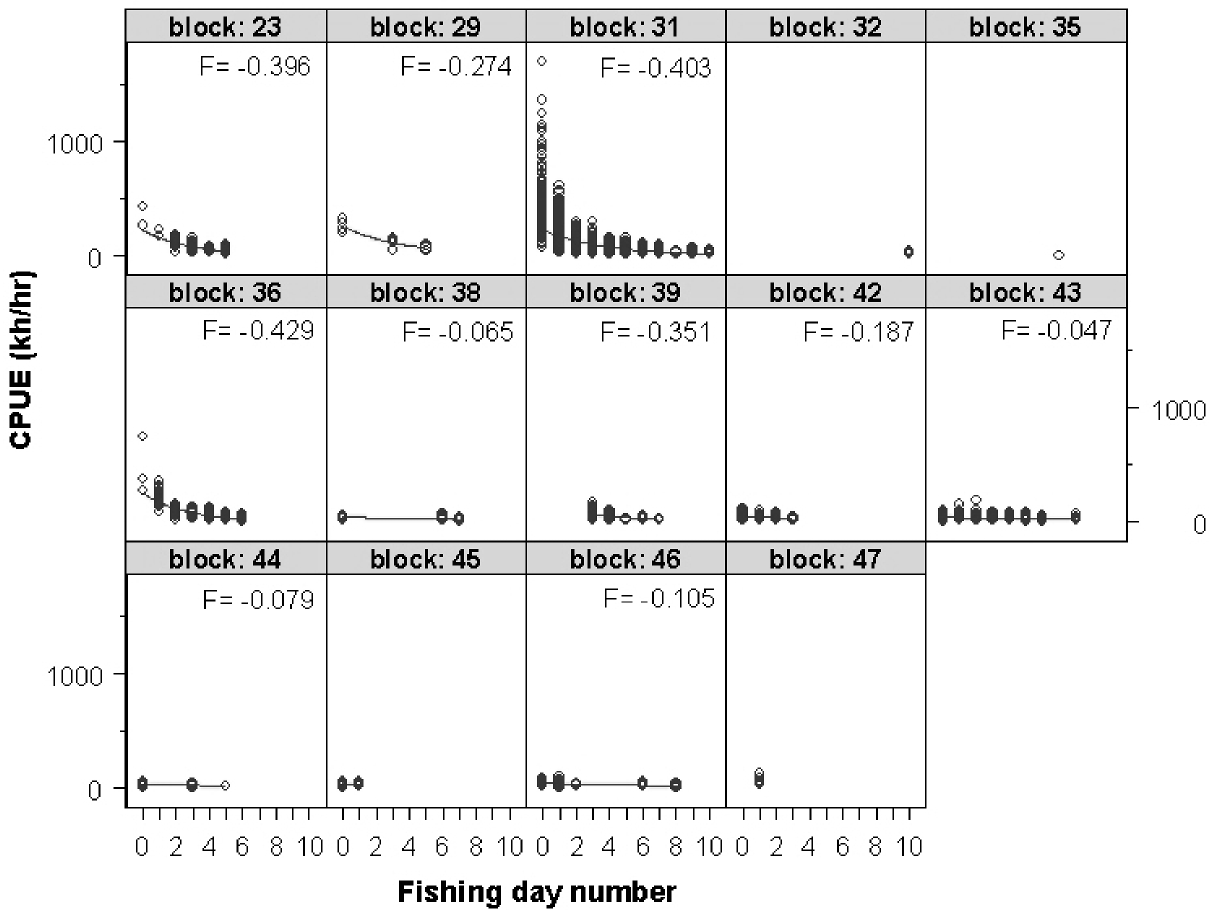


Figure 8.12: CPUE (kg/h) depletion by fishing day in April 1997 over Wallaroo and northern area grounds.

1998.

In 1998, harvesting of the Wallaroo region was 'delayed' to increase the value of catch, reduce depletion and provide greater scope for the fleet to spread (i.e. a wide opening of grounds) by opening the Wallaroo and Middle Bank grounds to fishing at the same time. The strategy was developed a day before fishing commenced using information obtained from a survey conducted one day before the opening of the grounds on April 26th . The fleet was able to disperse widely with high CPUE (Figure 8.13).

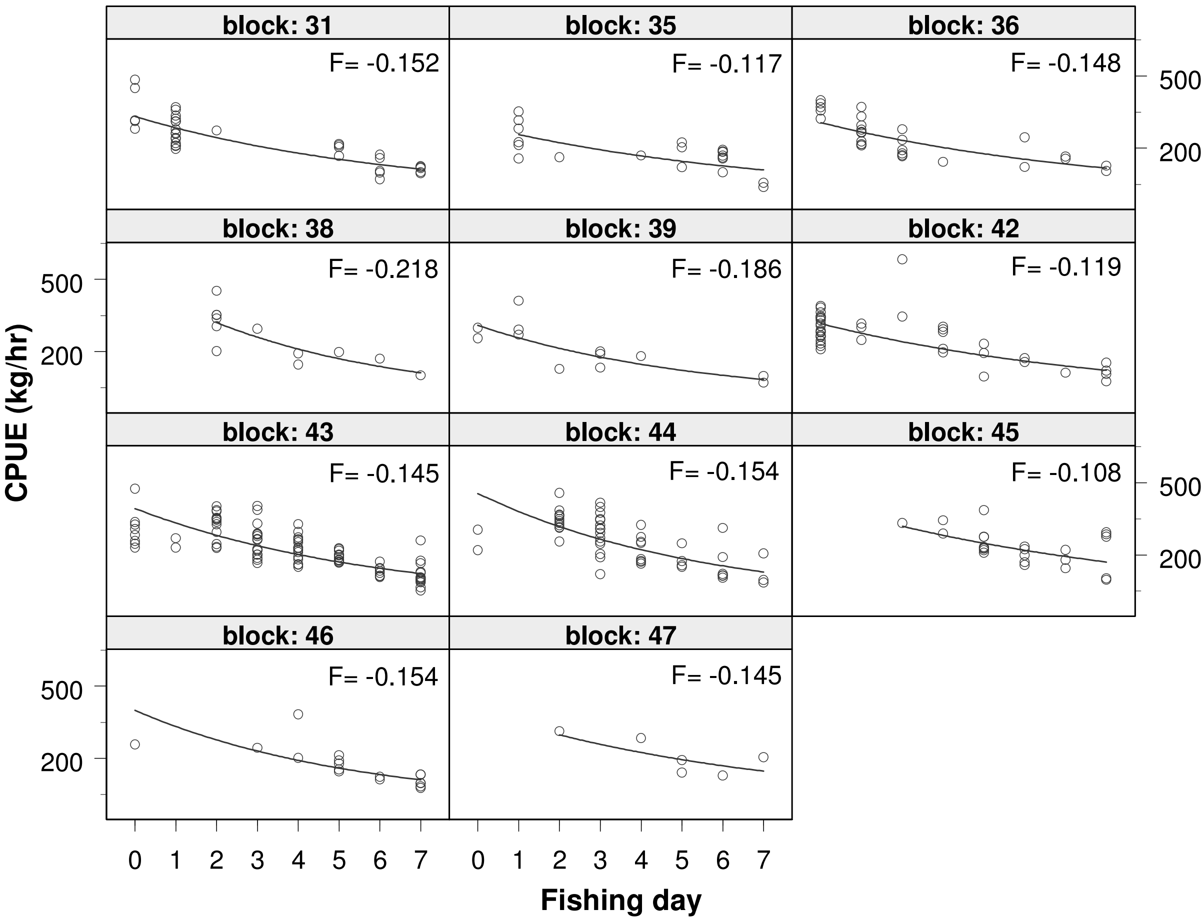


Figure 8.13: CPUE (kg/h) depletion by fishing day over fishing blocks in the April/May 1998 fishing period at Wallaroo and Middle Bank.

The daily instantaneous depletion rates for Wallaroo and the Middle Bank region were -0.127 and -0.147/day, respectively. The fleet depleted the biomass density by about 13% per day in the Wallaroo area and by 15% per day in the Middle Bank area (Figure 8.14).

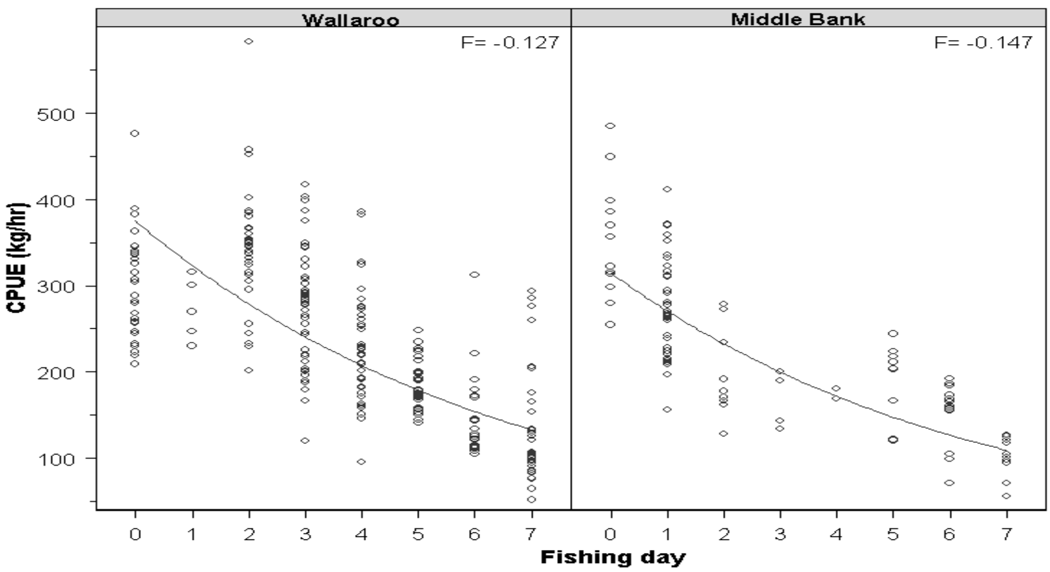


Figure 8.14: CPUE (kg/h) depletion by fishing day for the Wallaroo and Middle Bank regions, April/May 1998.

8.1.4 The relationship between catchability (q) and stock size (N).

The power curve (equation 3, above) fit to the data showed that the relationship between stock size (N) and catchability (q) was significant ($p<0.001$) and explained 68.7% of variance in the data (Figure 8.15). The slope (b) estimate was -0.97 ± 0.14 ($t = 7.051$) and significantly less than 0.

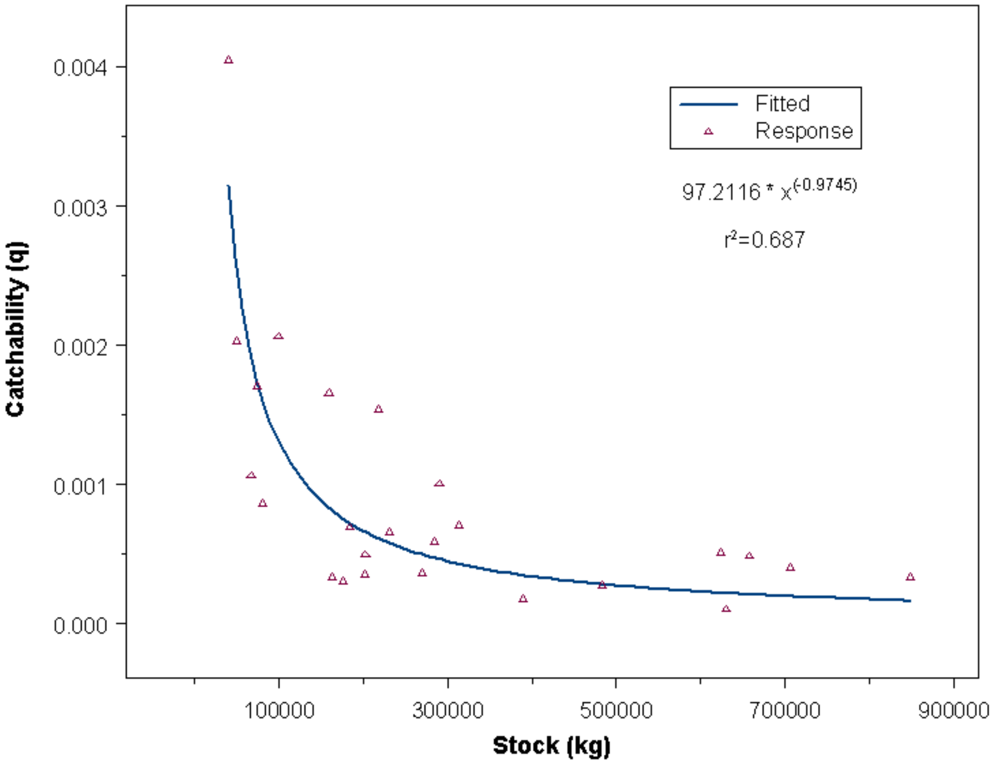


Figure 8.15: Relationship between the prawn catchability coefficient (q) from the Spencer Gulf prawn fishery and prawn stock biomass.

A nonlinear rectangular hyperbola (linear-divided-by-linear) model of the form q = A + B/(1 + D*Stock) was the best fit to the data with 74% of variance explained by the regression with a vertical asymptote at 28.5 tonnes which clearly indicates strong upward and non-constant slope of q at lower stock size. A simple linear regression model was a bad fit to the data and explained <10 % of the variance in the regression.

Linear regression of area (square nautical miles) on catchability (q) was a bad fit to the data with about 7.9% of the variance in the data with the slope being -0.021 (0.008, t = -2.64). A non linear rectangular hyperbola fit to the data explained 24.3% of the variance of the data and the derived relationship was: q = -0.496 + 5.96/ (1+0.091 x block area). Hence, the data indicates that catchability decreases with the size of a fishing block. However, the data used in the analyses was limited and more extensive analyses are required to derive a more accurate relationship between area and catchability (q).

Does searching and learning in the earlier part of the night results in an increase in rates towards the latter of operations (in early morning)? The daily patterns in the relationship between CPUE and trawl shot number (or dno) for April and May 2001 are illustrated in (Figure 8.16 and 8.17).

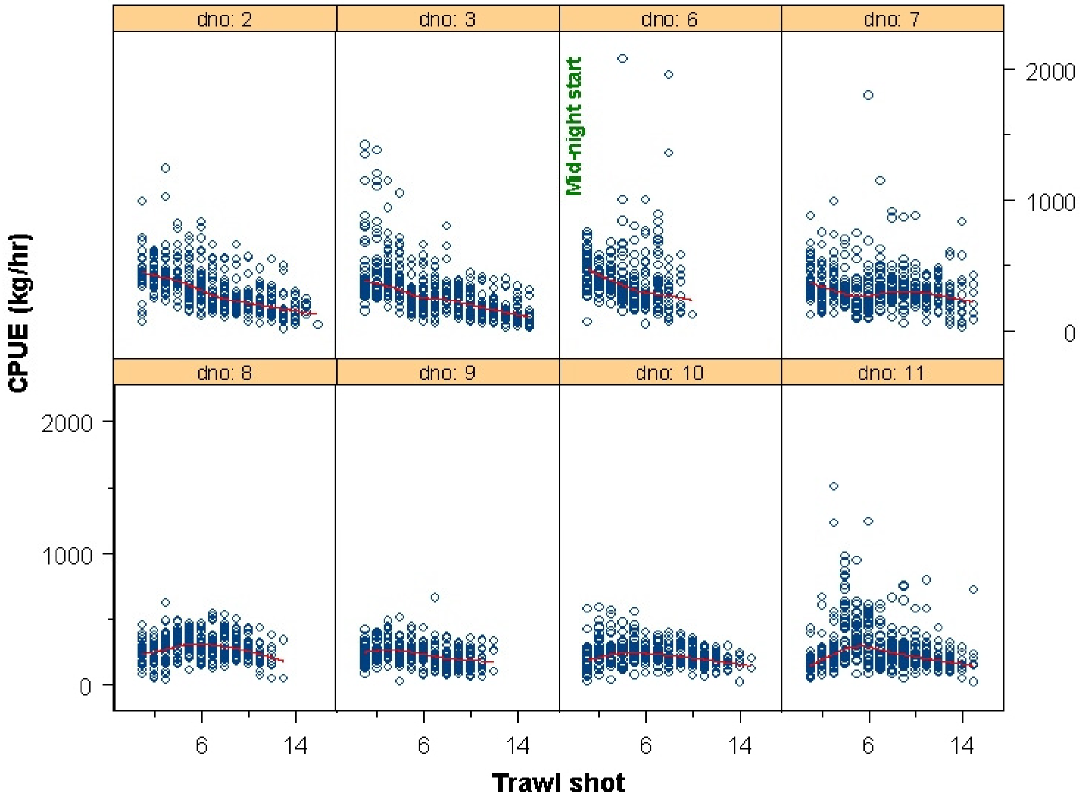


Figure 8.16: Relationship between trawl shot number and CPUE (kg/h) over fishing day (dno), April 2001, Spencer Gulf.

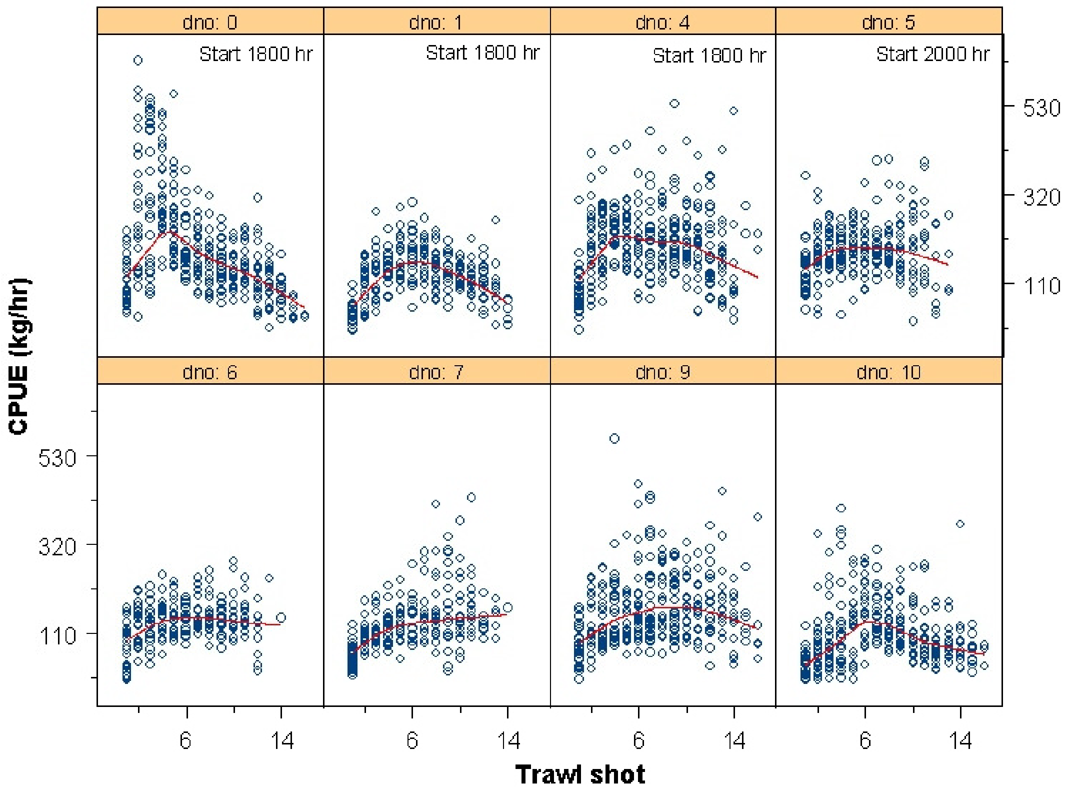


Figure 8.17: Relationship between trawl shot number and CPUE (kg/h) over fishing day (dno), May 2001, Spencer Gulf.

In April, there was no consistent indication that CPUE increased through the night with rates generally lower at the start and end of trawling and CPUE decreasing with trawl shot number, which is indicative of depletion. Residuals from the Poisson regression of CPUE with shot number nested within day number suggest nonlinear trends as indicated by plot of Pearson residuals which showed departure from linearity (Figure 8.18).

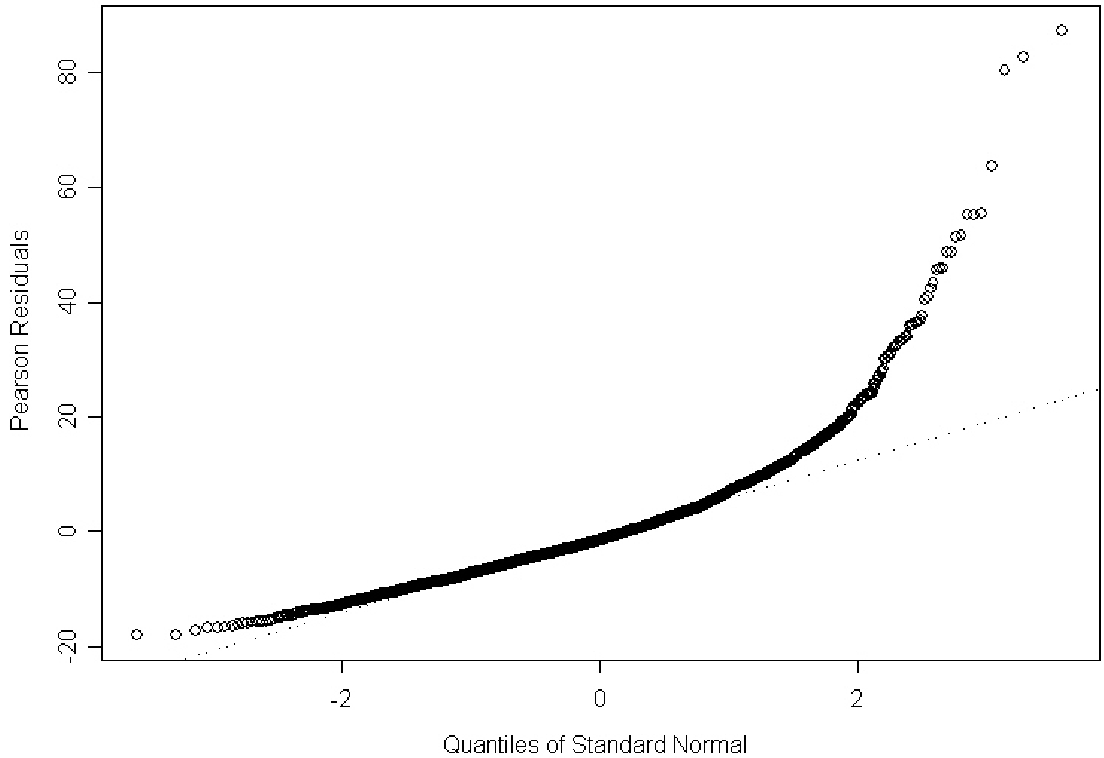


Figure 8.18: Pearson residual plots on quantiles for lm model of CPUE by shot number within fishing day number, April 2001, Spencer Gulf.

The Poisson regression, CPUE on day number/shot number, indicated significant ($p<0.005$) negative slopes (0.02 to 0.11) for shot number over each day except for day number 8 where the catch rate had a maximum at shot number 6. The overall Poison regression slope for shot number was – 0.047 ± 0.0003 and significant ($p< 0.001$, t value = 158.93).

The relationship between CPUE and shot number in May showed clear cases of nonlinear trends as reflected by the regression curves. The data was fitted to a nonlinear (double exponential, concave downward) model which explained 36% of the variance in the regression and was significant ($p<0.05$). The results did not show a consistent trend for CPUE increase through the night. However, there were cases where CPUE had maximum values through the night (approx. 2200 hr) which is more likely to be due to increase in prawn vulnerability (or availability) in response to tidal change (unpublished).

The results show that there is no consistent trend for an increase in catch rates with shot number which refutes the null hypothesis that catch rates increase through the night by searching and learning.

8.1.5 Discussion

Research showed that high depletion occurs by fishing Wallaroo too early in the year, which reduces the potential value of catch and the scope to spread the fleet in subsequent fishing periods, (Carrick and Evans 1998, Carrick 1999 b).The delayed harvesting strategy in 1998 allowed the fleet to fish down larger prawns in the southern area in March/April which resulted in increase in the prawn size composition of catch with >30% in the U10 grade (no/lb, head on) category (Figure 8.19). Of major significance was a substantial reduction in the percentage of smaller size grades in the Wallaroo and Middle Bank regions compared to previous years and a commensurate increase in the percentage of larger prawns (≤ 10/15 grade) in the catch. The results show that adaptive harvest strategies and real-time management can result in substantial economic gain but require diverse information including an understanding of temporal deletion rates, prawn dispersal and growth patterns.

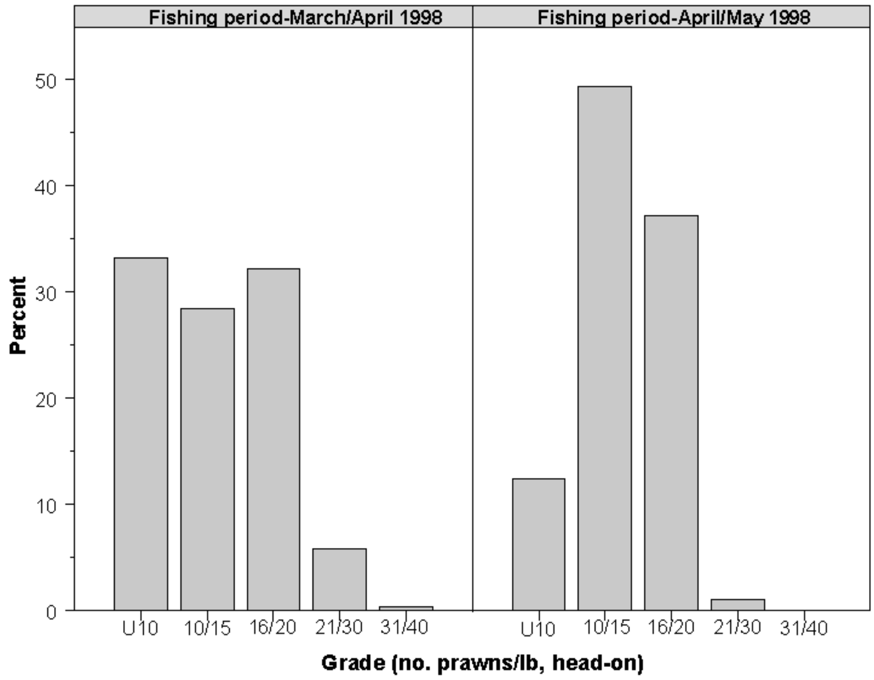


Figure 8.19: Size composition of prawn catch in Spencer Gulf in the March/April and April/May fishing periods in 1998.

The fishing mortality rates in the April/May fishing period were relatively low as the spatial distribution of abundance over grounds was high. The closure of Wallaroo in March 1998 was a successful experiment in adaptive management. It was designed to demonstrate to industry that substantial economic gain result from a delayed harvesting strategy, provide greater scope for the fleet to spread and would result in greater egg production (see below) which is a risk averse strategy for recruitment decline. Fishery-independent surveys were conducted to demonstrate the benefits and support information was obtained from real-time harvest simulation modelling used to predict optimal times to fish different spatial units of the stock.

The results show that trawl catchability is not constant and can vary with stock abundance, the spatial distribution of both prawns and patterns in fishing. The research supports the Paloheimo and Dickie (1964) hypothesis that q varies inversely with stock abundance (N) and the geographical area occupied by the stock. The results are the first demonstration of hyperstability in a penaeid prawn fishery. However, more extensive research is needed to address catchability (q) and vulnerability trends in South Australian prawn fisheries.

The Leslie depletion method is the most frequently used in fishery science for estimating stock size and depletion in trawl fisheries which have reliable data over spatial scales. A major problem identified in the analyses were cases of strong nonlinear (concave downward) relationship between cpue and fished day and between CPUE and cumulated catch which is expected to be attributable to prawn movement dispersal. The results demonstrate that CPUE will overestimate stock size at lower levels when assuming constant catchability. Hence, there is a need to use both fishery-independent trawl survey and commercial catch and effort data for stock assessment. The use of mark-recapture to determine movement dispersal parameters would provide valuable information which could be incorporated into stock assessment models. Prawn tagging experiments using tags (Hallprint or colour coded t-bars) and/or marking using injection methods would provide vital information on the fine scale spatial and temporal dispersal patterns needed to estimate depletion and stock size using catch and effort data. Furthermore, more extensive mark-recapture field experiments would provide valuable data for real-time adaptive management of the Spencer Gulf fishery.

Dichmont *et al*. (2003) developed a delay-difference model to catch and effort data to assess spawner and recruit trends in the Northern prawn fishery. They point out that the model was most sensitive to the value assumed for catchability (q) coefficient, temporal changes in fishing power and within-year effort distribution. MacCall (1976) applied the theory of density-dependent habitat selection to the spatial distribution of fish populations. A prediction from MacCall was the population range should expand with population size increasing with dispersal to poorer habitats as abundance and competition increase in better habitats. Swain and Sinclair (1994) developed a distribution index to quantify the spread of cod in Canada using fishery-independent surveys. Swain and Sinclair found a concave asymptotic relationship between cod abundance and the distribution index which would have large effect on catchability (q). The spatial spread of stock over a fisheries range is of significance to stock assessment and management as information indicates that stock declines in South Australian prawn fisheries were associated with a reduction in the spread of the distribution (unpublished).

The contraction of trawl grounds essentially reflects fisher's response to decline in both spread and abundance of stock. There are other cases where contraction of grounds has been reported in Australian marine fisheries and of relevance is the Northern Prawn fishery, (Dichmont *et al*. 2003). It is most important that fishery-independent survey data covering the spatial scale of prawn fisheries should be used with commercial catch and effort data for stock assessment. Commercial catch and effort data used as a sole tool for stock assessment has limitations as described above, especially when grounds contract due to changes in the spatial distribution of abundance.

If stock area was proportional to population size, catchability would increase as abundance decreases providing there is no change in variation (or selection) by fishers to different size prawns. Preliminary results indicate that catchability decreases with the size of a fishing block and that the slope is not constant, which supports the Paloheimo and Dickie hypothesis and the findings of Winter and Wheeler (1985). However, the simple depletion model (CPUE on day) would be confounded due to variation in abundance and area, movement dispersal and fisher behaviour. Incorporation of fishing block area in GLM, Reml and Anova as a covariate can reduce bias in the comparison of trends in CPUE (unpublished). However, it was assumed that fishing takes place uniformly throughout fishing blocks which is not the case. GPS point data based on individual shots over all vessels would allow more precise estimates of the actual area fished and spread of effort within blocks and over the region, resulting in improved stock assessment.

The re-design and implementation of the new Spencer Gulf daily logbook was considered a significant achievement of the FRDC study with the objective to obtain more reliable data on the spatial distribution of CPUE and stock within and between fishing blocks. However, results obtained from the 'new' log book system demonstrate that reliable data can only be obtained by automated electronic data transfer (see above).

The underlying causes of an increase in q with declining stock abundance can be due to a number of factors including improvements in fishing power (fishing performance) of the fleet, non-random targeting by fishers on aggregations following change in stock distribution and abundance and by pulse movements and aggregations of prawns. In these circumstances commercial CPUE is a reliable index of prawn stock density but a biased index of stock abundance. It is hypothesised that:

- Prawn movement dispersal is density dependent.
- Trawling will homogenise an otherwise heterogeneous system which has important implications to fishery sustainability if prawn aggregations are associated with mating and spawning (see below).

The results for Spencer Gulf show that there is no consistent trend for an increase in catch rates with shot number, which refutes the null hypothesis that catch rates increase through the night by searching and learning. The detection of a maximum catch rate in the earlier part of the night for May is likely to be attributable to increased availability associated with larger tide flow, moonlight illumination and learning which are confounded. The results show that catch rates generally decline with the number of shots through the night due to depletion. Only in years when stock levels are low would searching have significant influence on catch rate trends between and within nights. It is likely that 'learning' or prior knowledge obtained by Spencer Gulf fishers about catch rates is obtained rapidly (by the 1-4 trawl shot within a night) through communication and electronic 'tracking' of competing groups and by information provided on trawl survey results. The results obtained for Spencer Gulf appear different to those reported in the Gulf St Vincent fishery (GSV) by Xiao (2004). Xiao showed that CPUE increases over a night in the less competitive GSV fishery. The GSV fleet conducts frequent coordinated searching operations which are somewhat unique in a fishery. If there was an increase in rates with shot number in Spencer Gulf, the relationship between catch and effort would require a non-linear parameter (λ) to account for the combined effect of searching and learning on catchability (Xiao 2004, Wang et al. 1999).

Fishery-independent trawl surveys were set up in 1981 with the purpose of obtaining long term data on the spatial and temporal distribution of the stock, recruits and spawners. The spatial scale of survey operations (and sampling intensity) increased over time, especially over the period of the FRDC study. There is now a need to 'optimise' sampling plans, a non-trivial task requiring the understanding of spatial processes and the analyses required for stock assessment and management. There is need for more objective methods to estimate fishery parameters than those based solely on fishery-dependent trawl data. The parameters estimated by the catch equation based on commercial catch and effort data (and other derivatives) are frequently confounded and result in bias due to same terms being included on each side of the equation. However, assessment of stock size and depletion using fishery-independent surveys is less prone to confounding and would be of greater value if estimates of seasonal variation in vulnerability (catchability) and dispersal indices were included in the derivation of parameters.

Most penaeid prawns display strong diurnal and seasonal variations in vulnerability (or availability) to capture due to behavioural responses to water clarity, moonlight illumination, tidal amplitude and water temperature, (Dall *et al*. 1990). There are endogenous rhythms for burrowing behaviour with movement dispersal expected to be associated with density dependence, habitat selection and, in *Penaeus melicertus,* aggregation may be a response to increase the success of breeding. Joll and Penn (1990) found that prawn “catchability” varied with sex, size and season in Western Australia. Prawn vulnerability variation due to prawn behavioural responses through night and lunar phase have an effect on “catchability” (personal observation). It is suggested that field research studies be conducted to estimate variations in prawn vulnerability (or availability) associated with sex, size, month (or season) and lunar phase, which would significantly improve stock assessments.

8.2 Fishery-independent assessment of the influence of prawn dispersal and density changes on the value of catch in Spencer Gulf

8.2.1 Background

Mark release-recapture studies in Spencer Gulf have shown that a large scale movement of prawns occurs from February to April with a movement from the northern area to the Wallaroo region. Furthermore, results have shown that negligible movement of prawns takes place from the Wallaroo region. Harvest modelling simulation has shown that postponing fishing from February to April/May at strategic areas (e.g., Wallaroo and Middle Bank) results in a substantial increase in the value of catch due to an increase in biomass and in the size composition of the catch. Prior to 1998, harvest strategies adapted for the Wallaroo region took place too early as fishing began in February/March and resulted in waste in trawl value, substantial local depletion and increased "pressure" on management to open more grounds even though prawns were below optimum harvest size, (see above). A number of attempts (from 1988) were made to reduce the depletion at Wallaroo from February to early April, especially on smaller prawns which have been shown to move into the Wallaroo area from February. In 1998, an 'experimental' manipulation of the fleet was conducted to demonstrate the benefits of closing Wallaroo from February to April where changes in biomass densities and trawl value ($/h) were determined by fishery-independent trawl surveys. An additional test was undertaken in February, April and November 2001. The objectives of the field studies were:

1. To determine spatial changes in prawn distribution and trawl value ($/h trawled) from February to April when the region was closed to fishing.
2. To demonstrate that spatial changes in prawn density and value are due to movement dispersal and biomass growth.
3. To demonstrate the benefits of closing Wallaroo to trawling from February to April using fishery-independent surveys and corroborate results obtained from depletion studies based on commercial catch and effort data.

It was predicted that the Wallaroo temporal closure would result in the following benefits to the fishery by:

- Increase the value of catch.
- A greater spread of the fleet.
- Reduced potential to open other areas in the north where prawns were below optimum harvest size.
- Reduced "waste" and increase in the value of the catch by forcing the fleet south to larger prawns in March.

Trawl value is a function of biomass and prawn size. Gains in prawn growth from February to May exceed losses attributable to natural mortality resulting in increase in biomass and prawn size. No loss in biomass can occur by movement of prawns out of the area as prawn tagging results demonstrated that negligible movement from the Wallaroo area takes place. It was predicted that closure of the Wallaroo region from February to April would allow prawns to disperse through more area with a greater number of high density "patches" (aggregations) of high value. It has been shown that high fishing mortalities occur from April to May due to aggregation and smaller area. Hence, harnessing effort (e.g., February-April) would result in greater spread of the fleet in subsequent fishing periods, especially blocks 39, 36, 35, and 31 in May.

8.2.2 Methods

Two experimental tests were undertaken using fishery-independent trawl surveys. The first was conducted in February and April 1998 and the second in February, April and November 2001. Data was subjected to the NT7 procedure to determine spatial and temporal changes in density (no. prawns/hour), biomass density (kg/hour), trawl value ($/h) over the experimental regions (i.e. Northern, Wallaroo and northern Gutter areas). Fishery-independent trawl surveys were used to compare temporal changes in prawn distribution, trawl value ($/h) and prawn size grades in February and April 1998 before fishing took place. Fishing did not take place in April before survey sampling and the November 2001 survey allowed the assessment of the effect of fishing from April to June. Data was mapped to visualise dynamic changes and subjected to REML to test the main effects of Month (February, April & November), Area (North versus Wallaroo & Gutter) and the Month x Area interaction. The total number of sampling sites in 1998 ranged from 41-44 with 21-22 sites in the North and 20-21 sites at Wallaroo. The total number of sampling sites for the 2001 experiment was increased and ranged from 124-127, with 93-101 sites in the North and 28-31 sites in the Wallaroo & Gutter area.

Fishery-independent trawl survey data from surveys conducted in February 1998 and 2001 were used to simulate trawl value increases from February to May. The SQL Plus procedure NT8 was used to generate the size structure (mm CL) of male and female prawns from trawl stations sampled at Wallaroo and Middle Bank in the February period. Size frequency data from each sampling site was subjected to a harvest simulation written in Genstat 5 to determine the monthly changes in trawl value. The input to the harvest simulation model included size frequency samples, derived growth parameters, prawn price structure (from processors), natural mortality estimate (M = -0.07 month) and prawn seasonal vulnerability indices derived from background work A non-parametric bootstrap was used to derive mean and standard errors in estimates of trawl value increments. An estimate of the increase in fishery value by adapting a harvest strategy which delayed fishing at Wallaroo in February 1998 was obtained, based on daily fishing mortality estimates generated by the fishery over a ten day fishing period in April/May.

8.2.3 Results

Spatial changes in prawn density, trawl value from February to April, 1998.

In February 1998, a large aggregation of prawns was situated north of Middle Bank and the biomass density was relatively low at Wallaroo, except for an aggregation in the central part of the region (Figure 8.20). In April, there was a large increase in both the biomass density and the dispersal (spread) over the Wallaroo grounds.

The biomass density spatial profile indicated strong latitudinal changes with the highest prawn density situated north of Middle Bank in February which changed to south of Middle Bank in April (Figure 8.21). The large increase in prawn biomass density from 33.65°-33.9° S supports the hypothesis that strong prawn movement dispersal to Wallaroo from the north occurs from February to March.

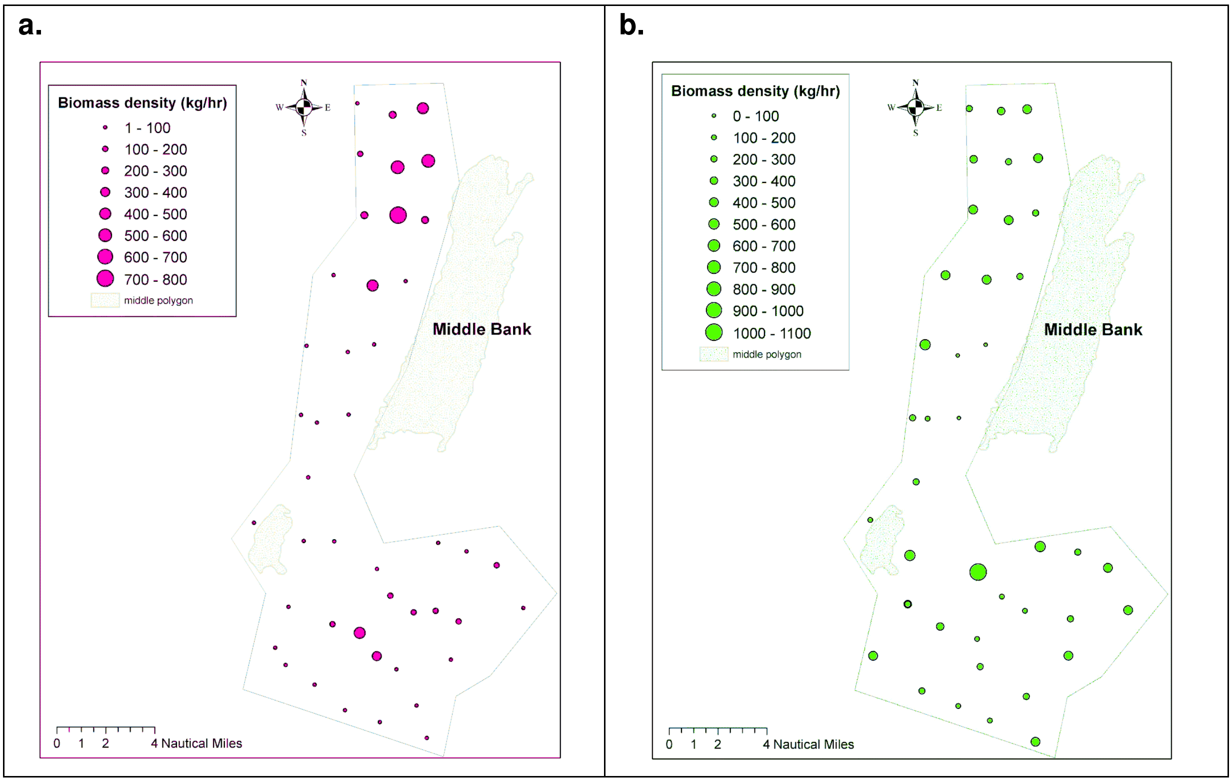


Figure 8.20: Trawl survey biomass density (kg/h) distribution over the Middle Bank and Wallaroo trawl grounds in (a) February & (b) April 1998 with a boundary enclosing trawl sampling sites.

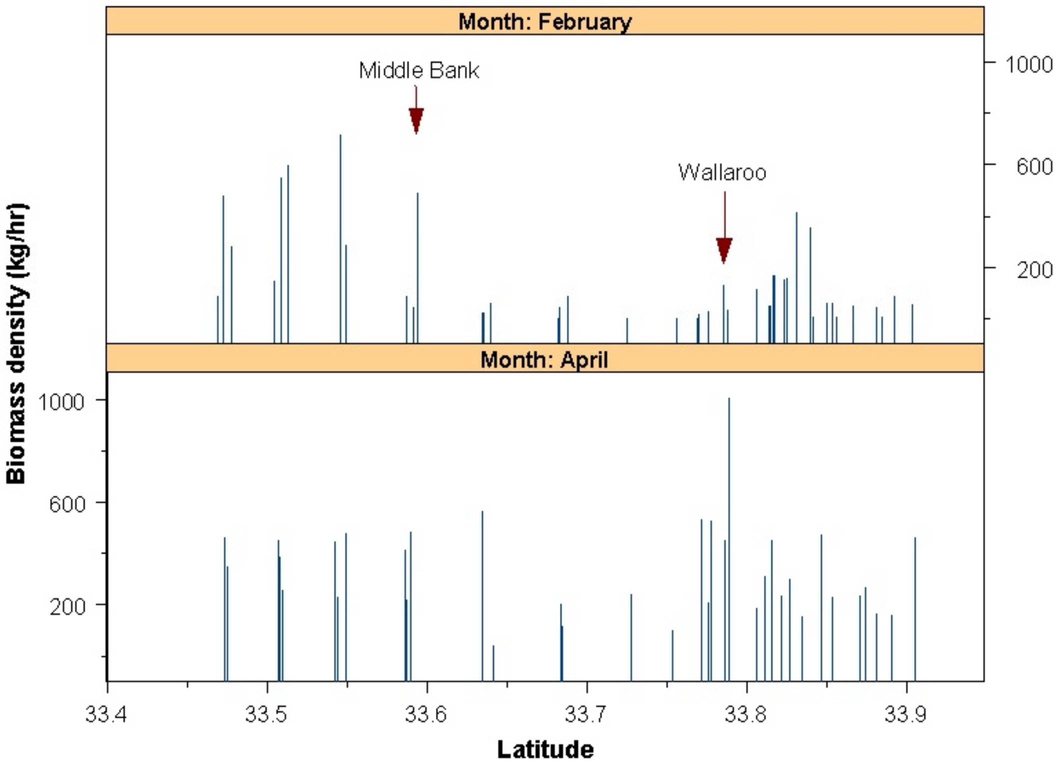


Figure 8.21: Changes in biomass density (kg/h) profiles over February and May, 1998.

Changes in the biomass density from February to April tend to be mirrored by trawl value ($/h) but the increase in trawl value at Wallaroo and the spread over sampling sites was most marked (Figure 8.22 and Figure 8.23). The results show strong concentration profiles in trawl value north of Middle Bank in February with a large change in trawl value spatial distribution in April where highest concentrations were found at Wallaroo.

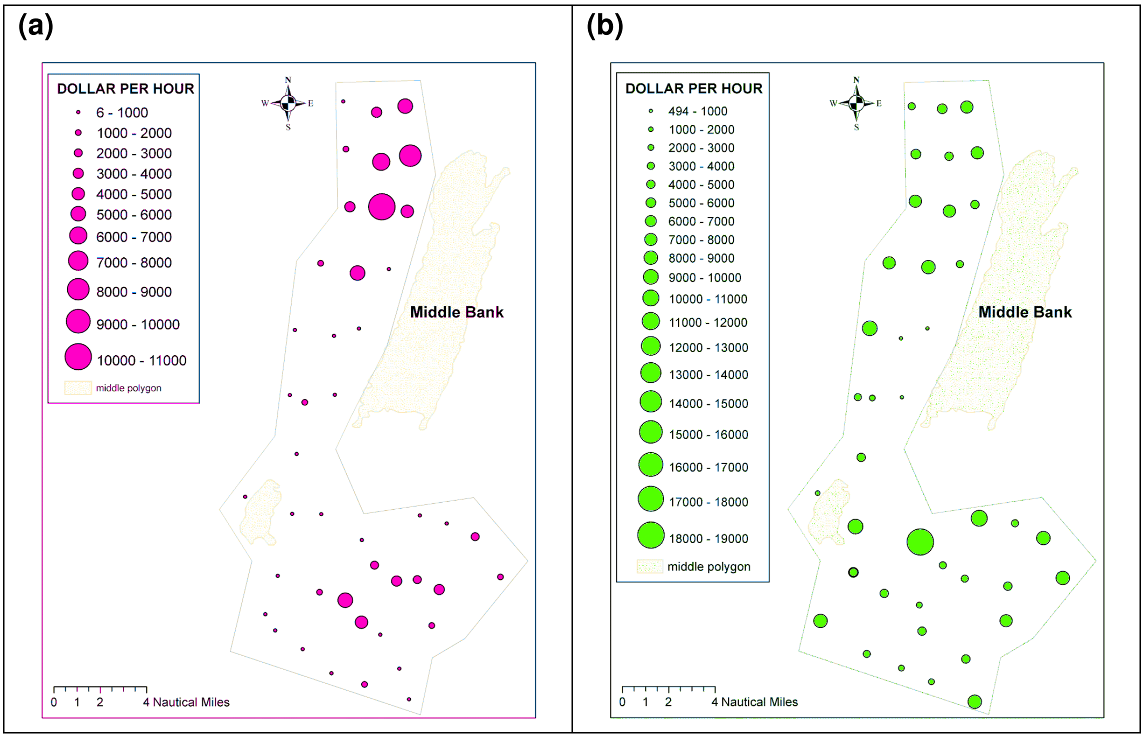


Figure 8.22: Trawl value ($/h) distribution over the Middle Bank and Wallaroo trawl grounds in (a) February & (b) April 1998.

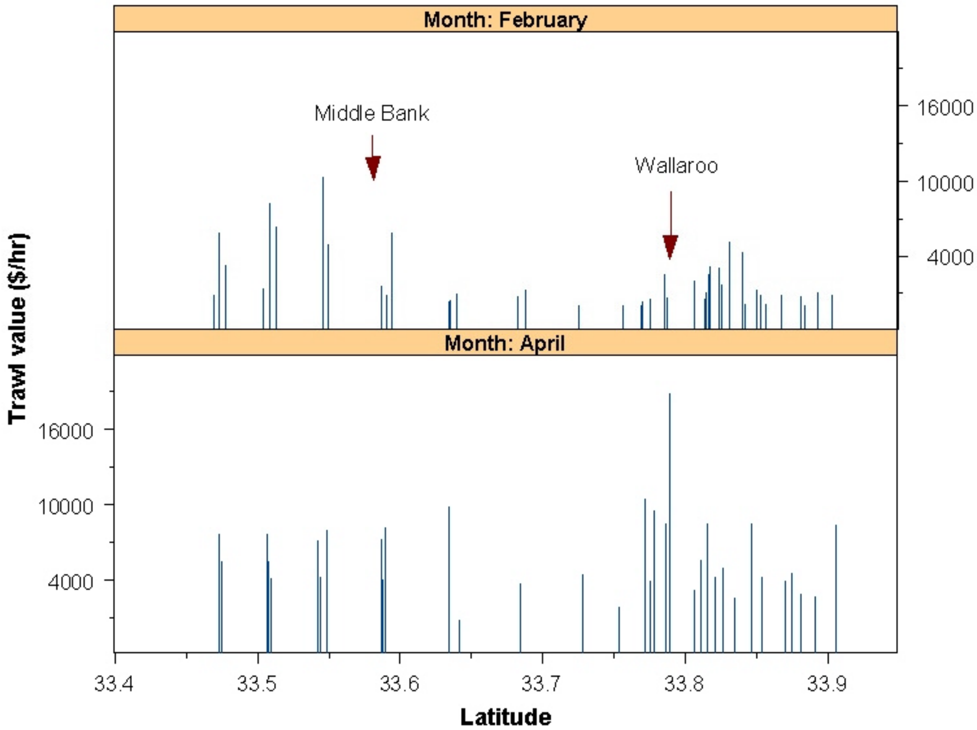


Figure 8.23: Changes in trawl value ($/h) density profiles over February and May, 1998.

The prawn density (no prawns/hour) distribution was highly skewed, with values exceeding15 000 prawns/h in the Middle Bank area in February. From February to April there was a 14.4% increase in the mean density of prawns in the Middle Bank area whereas at Wallaroo the density increased by about 150% (or 2.5 magnitude change) with the mean increasing from 4 020 ± 1 197 prawns/hour to 10 042 ± 174.0 (Figure 8.24). The mean trawl value increased from $1 498 ± 295 to $6 025 ± 853/h from February to April at Wallaroo which represents a 300% increase. The value increase in the northern area was about 96% with the mean increasing from $2 540 to $4 987/h (Figure 8.24).The percentage gain in trawl value at Wallaroo compared to biomass increase was attributable to a larger size composition.

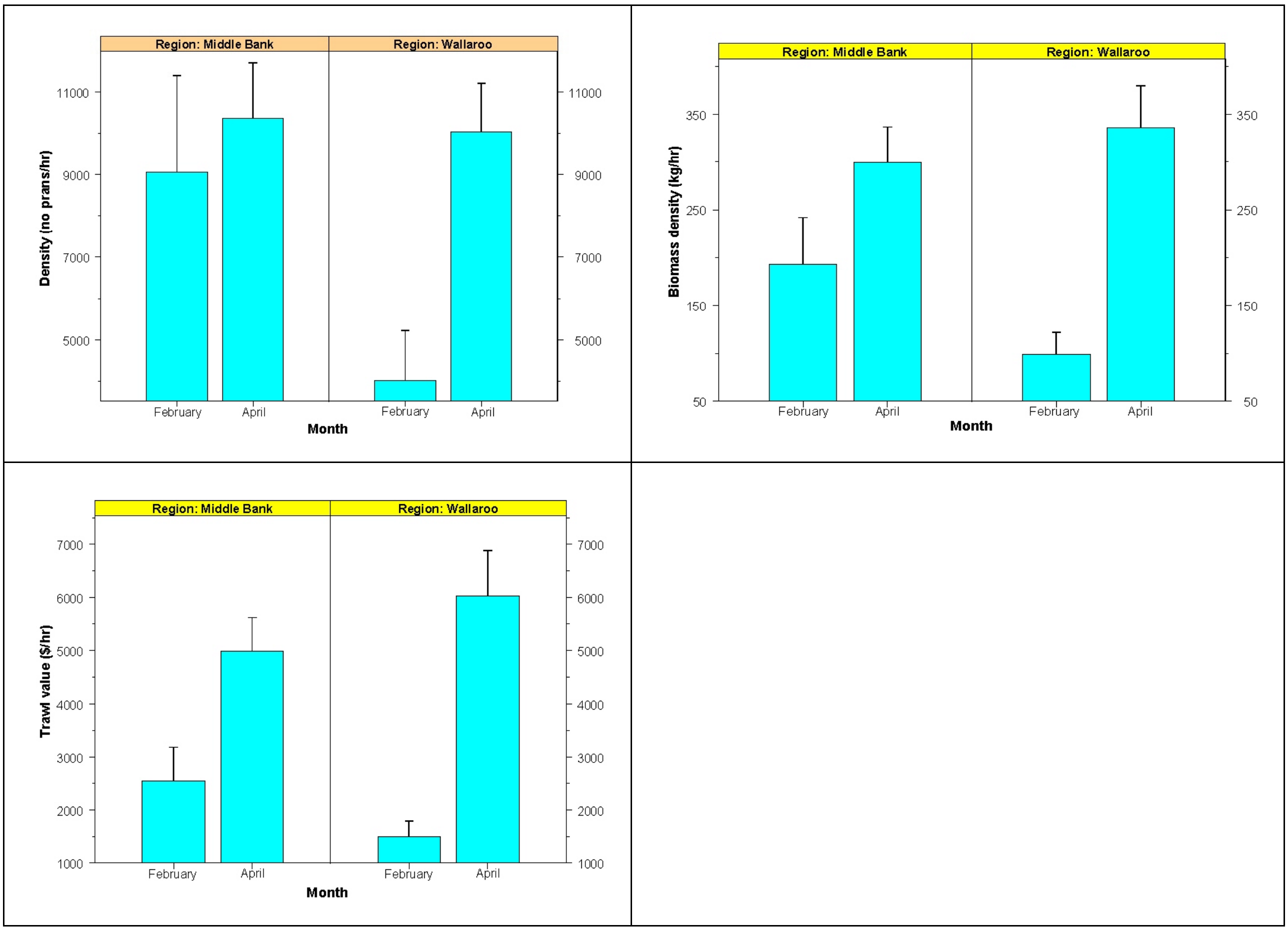


Figure 8.24: Comparisons of mean (se) prawn densities (number and kg/h) and trawl value ($/h) over Middle Bank and Wallaroo in February & April 1998.

Prawn number, biomass and trawl value data was square root transformed to homogenise variance and subjected to a REML model with the fixed component being Constant + Region + Month + Region.Month and the random component was Region.Rep. For prawn density (no/h), only the Month effect was significant ($p<0.001$) and the Region x Month interaction was not significant (Wald statistic 2.67, $p = 0.102$) indicating that both regions had a similar response over Month. The Region x Month interactions for biomass density (kg/h) and trawl value ($/h) were not significant. The results indicate that all response variates over both regions increased from February to April. The large increase in prawn density (no prawns/h) in the Wallaroo region was attributed to prawn movement dispersal to the region.

Spatial changes in prawn size grades from February to April, 1998.

The results show that the distribution of larger size grades increased from February to April. The mean biomass of 6/10, 10/15 and 16/20 size grades (no/lb, head on) largely increased from February to April 1998 (Figure 8.25). In February, the mean biomass of the 21/25 grade was 65.0 kg/h at Middle Bank (region 1) which declined to 38.1 kg/h in April with a commensurate increase in larger size grades (10/15 and 16/20 counts). The mean biomass density of the 10/15 and 16/20 grades at Middle bank increased from 23.2 -117 and 36.4-122.8 kg/h, respectively. The biomass of the bigger prawn grades at Wallaroo (region 3) increased largely from February to April. There were mean biomass increases from 28.3 - 34.6, 21.4 -118.0 and 16.4-118.2 68.2 kg/h for 6/10, 10/15 and 16/20 grades, respectively.

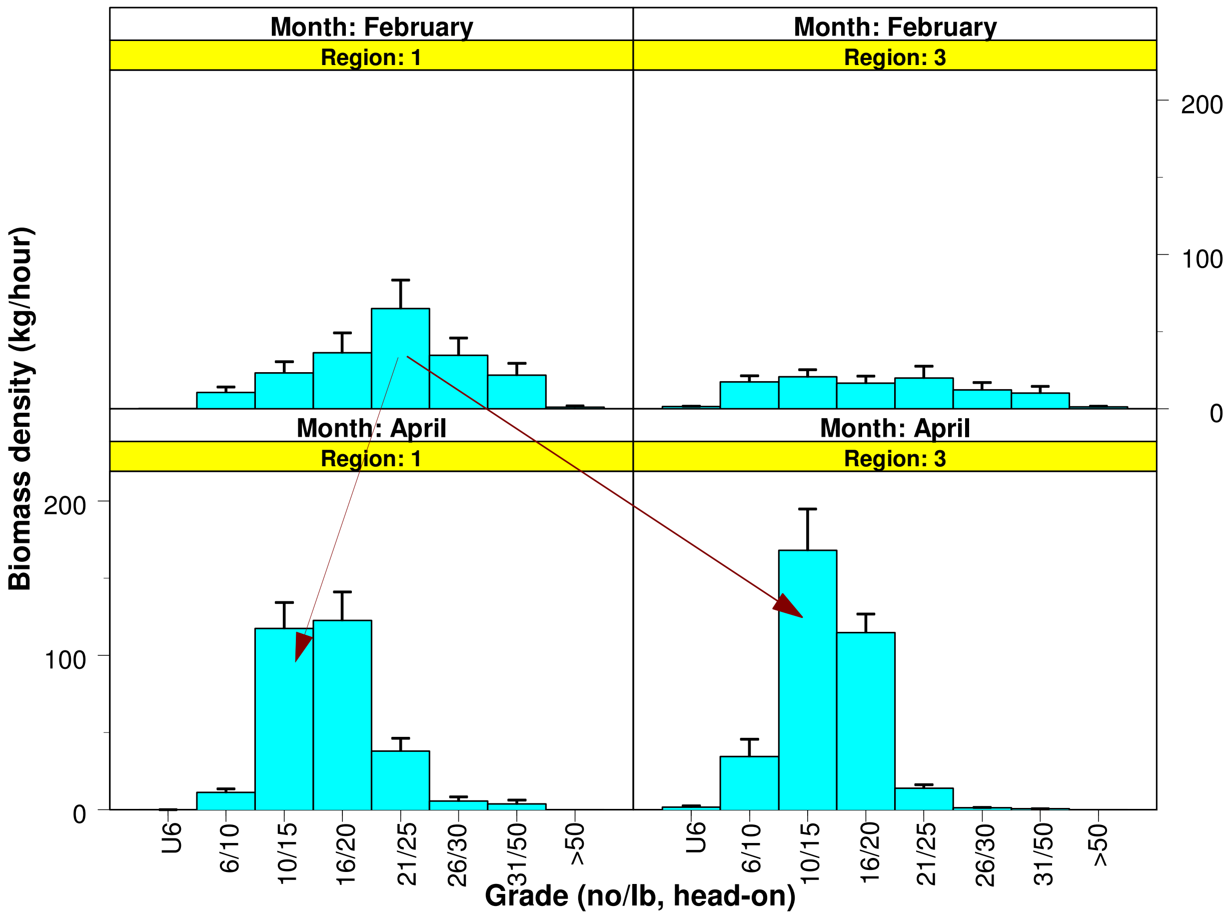


Figure 8.25: Mean biomass density (kg/h) change over 8 size grade (no/lb, head on) categories from February to April 1998 at Middle Bank (region 1) and Wallaroo (region 2). Estimates derived from NT7 using fishery-independent trawl survey data.

The temporal change in the spatial distribution in biomass density (kg/h) for 6/10, 10/15 and 16/20 prawn grades (prawns/lb, head on) reflect changes due to growth and movement dispersal (Figure 8.26 - Figure 8.28). The 6/10 grade declined at Middle Bank increased at Wallaroo from February to April with largest aggregation occurring in the northern sector of Wallaroo (Figure 8.26 a & b). Results show that the spatial density of 10/15 grades were more widely distributed and more abundant in both areas in April compared to February with highest aggregations occurring in the northern sector of Wallaroo. Premium prices are paid for larger prawn grades (6/10, 10/15) which are targeted by fishers when biomass density is high. Larger size female prawns dominate the larger grades which contribute largely to egg production when in high densities, (see below).

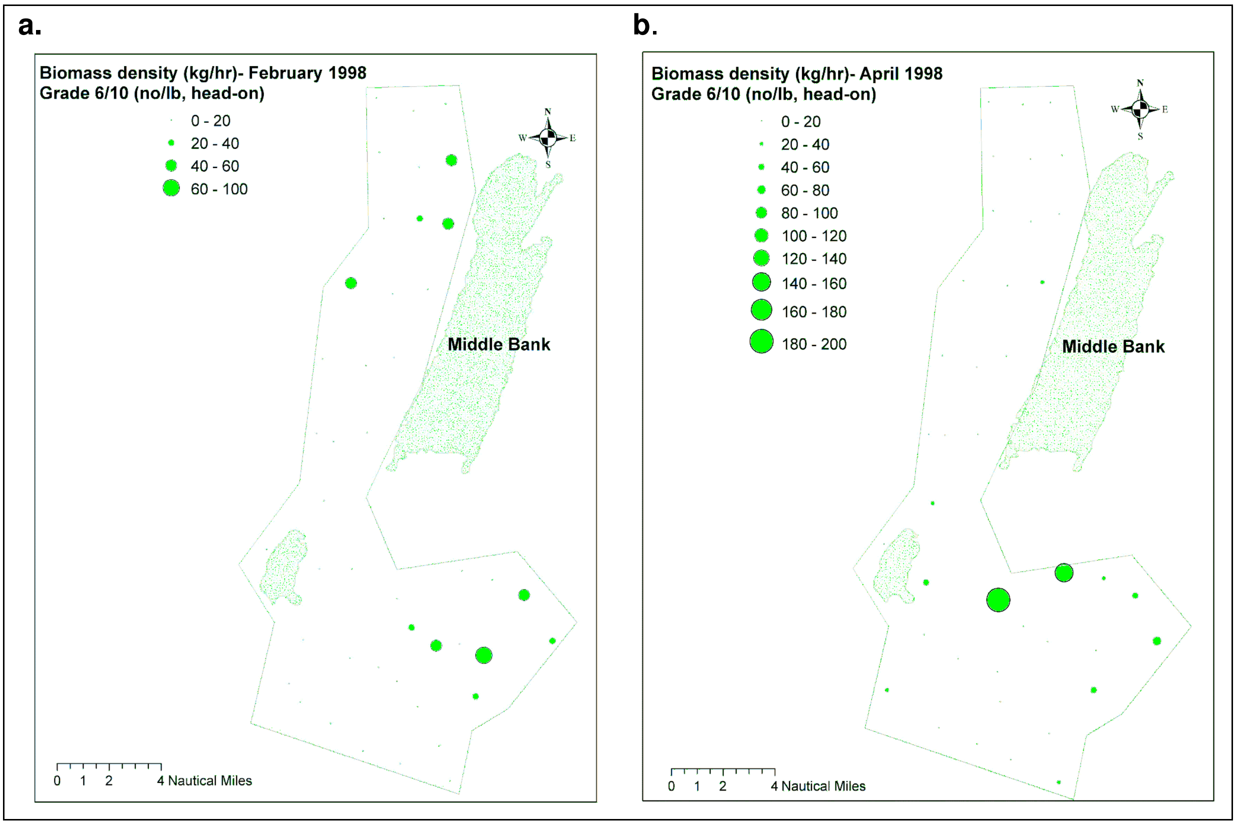


Figure 8.26: Biomass density (kg/h) distribution of prawn 6/10 grade at Wallaroo and Middle Bank regions in 1998-(a) February & (b) April 1998.

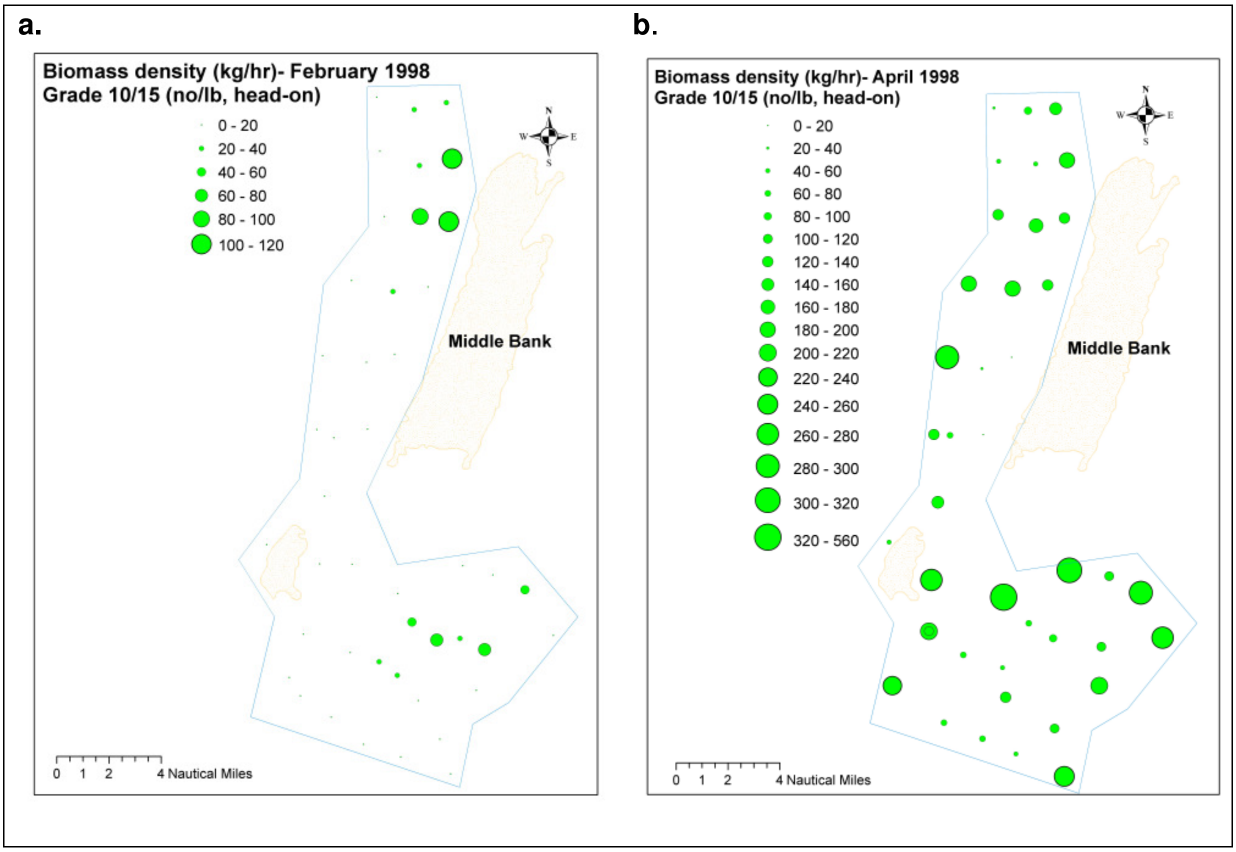


Figure 8.27: Biomass density distribution of prawn 10/15 grade at Wallaroo and Middle Bank regions in 1998-(a) February & (b) April 1998.

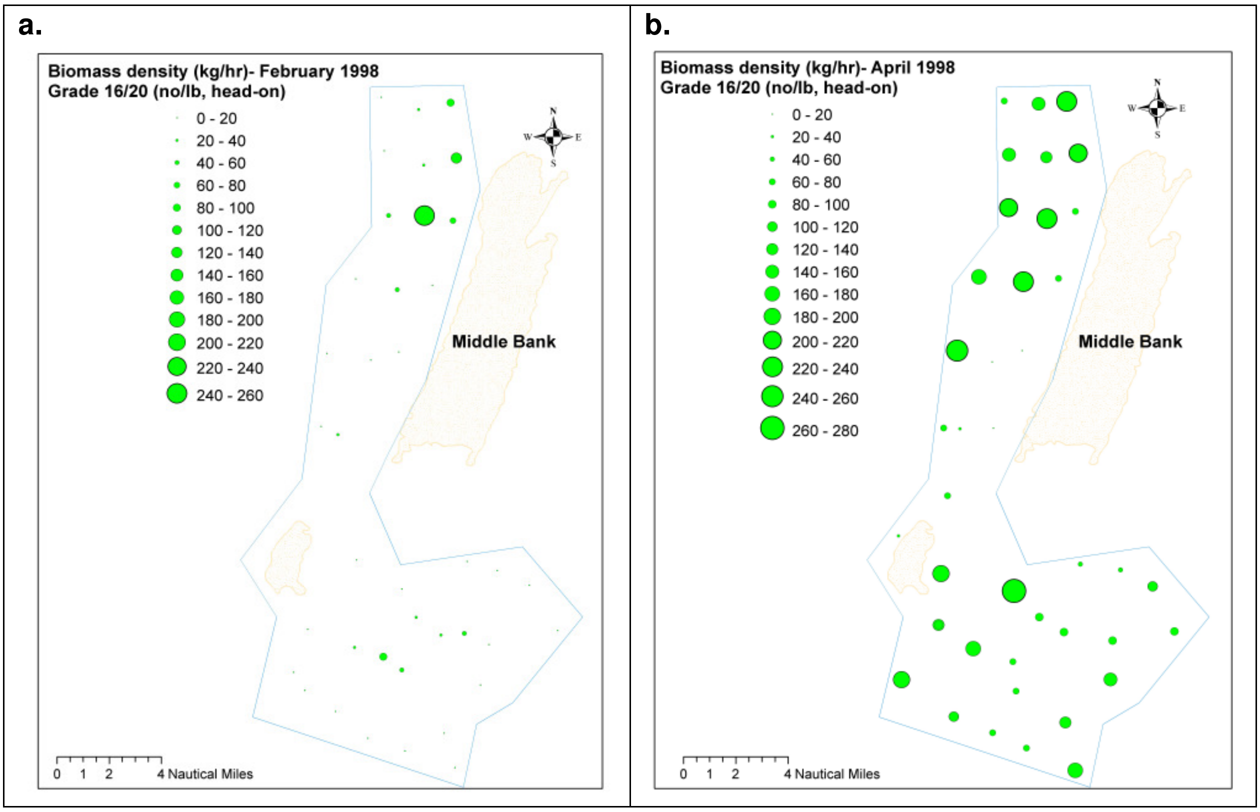


Figure 8.28: Biomass density (kg/h) distribution of prawn 16/20 grade at Wallaroo and Middle Bank regions in 1998-(a) February & (b) April 1998.

Spatial changes in prawn density and trawl value in February, April and November 2001.

Maps of prawn densities (no prawns/h, kg/h) and trawl value ($/h) from February to April 2001 in the Northern and Wallaroo-Gutter areas before fishing (February and April) and after fishing (November) show large changes in spatial patterns (Figure 8.29). In February, highest densities (no prawns/h) were situated in the northern sector of the Middle Bank region (Figure 8.29 a).

In April, there was a large change in the spatial density distribution with a large increase in density at Wallaroo and a reduction in density at Middle Bank compared with February (Figure 8.29 b) with largest aggregations occurring north of Middle Bank on the eastern and western sides of the region. In November 2001, the spatial distribution of prawns changed with highest density aggregations occurring near Whyalla in the northern section of the study area (Figure 8.29 c).

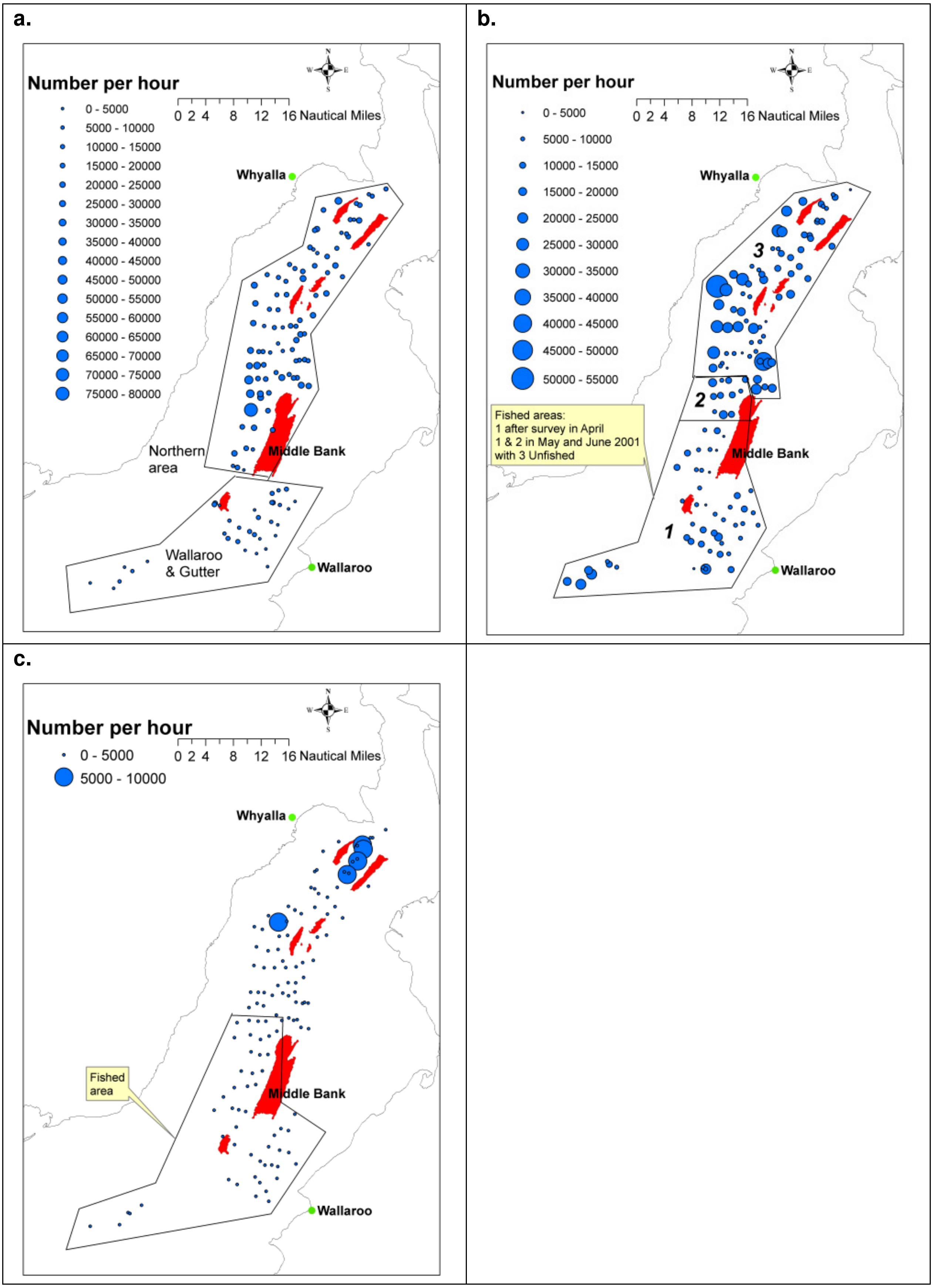


Figure 8.29: Spatial and temporal changes in prawn density (no./h) in Spencer Gulf from February to November 2001-(a) February; (b) April where 1 & 2 are Fished and 3 the Unfished regions; (c)-November.

Similarly, the spatial density profiles show strong changes with latitude from February to April 2001, which was attributed to movement dispersal from north to south (Figure 8.30). The effect of fishing on density dispersion is to homogenise variation which is reflected by the similar density levels from 33.5°-34.0° S in November (after fishing) compared with the more heterogeneous density patterns in that area in April (before fishing).

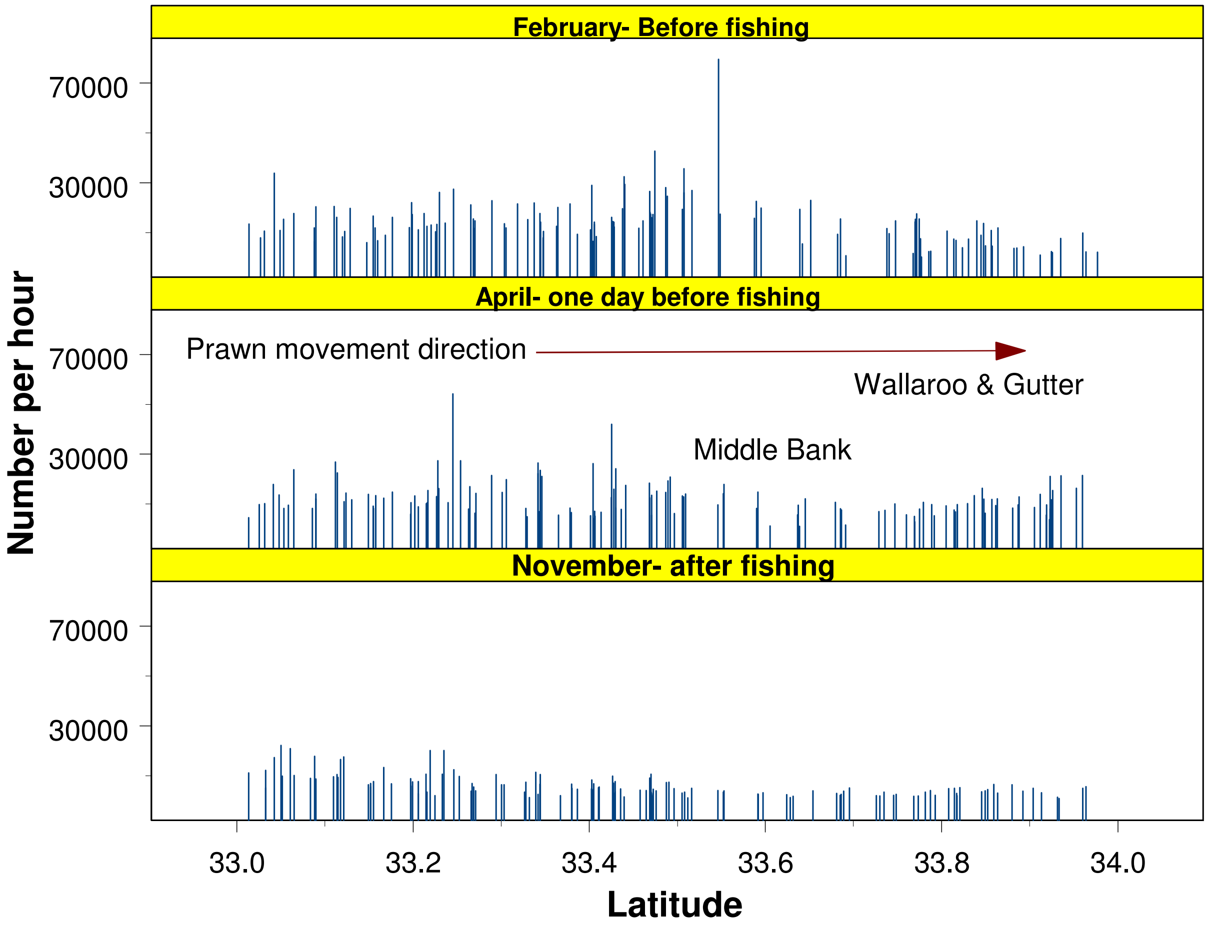


Figure 8.30: Latitudinal changes in prawn density (no. prawns/h) in February, April and November 2001.

Biomass density (kg/h) patterns changed from February to April with highest biomass density and large prawn aggregation occurring at Middle Bank in February (Figure 8.31). There was a large increase in biomass density distribution (spread) over the Wallaroo ground from February to April (Figure 8.31a & b). The variance (an indicator of dispersion) for the northern area in April was about 1/3 of that in February; whereas it was twice as large in April at the Wallaroo area. In November, highest biomass density was situated in the northern sector of the Gulf which was not fished due to management constraints. The effect of fishing is reflected in reduced biomass and more homogenous density patterns in the fished areas (Figure 8.31c & Figure 8.32). The results indicate that movement dispersal resulted in the reduction of mean biomass from February to April in the north.

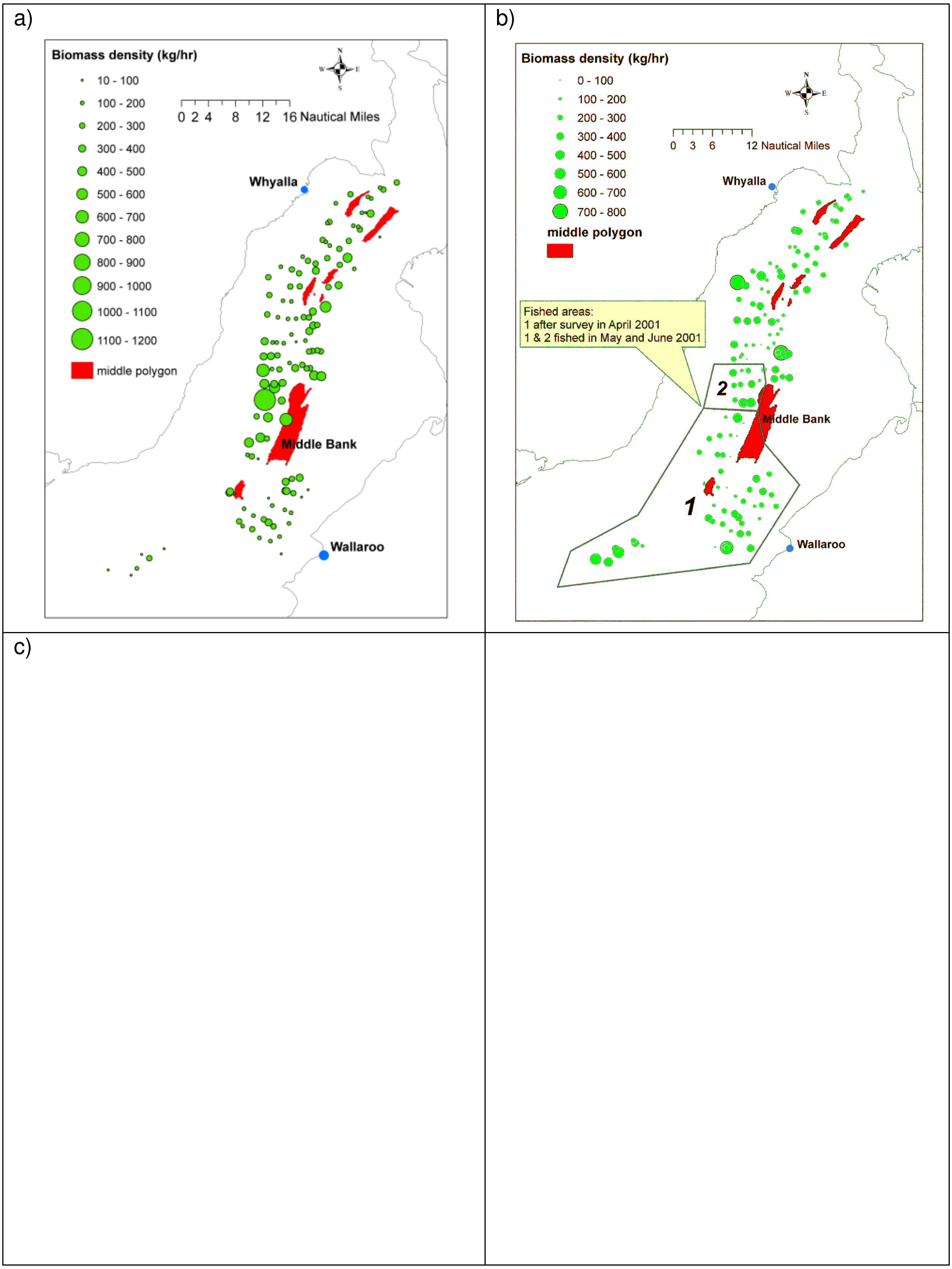


Figure 8.31: Spatial and temporal changes in biomass density (kg/h) in Spencer Gulf from February to November 2001-(a) February; (b) April where 1 & 2 are Fished and 3 the unfished regions; (c)-November.

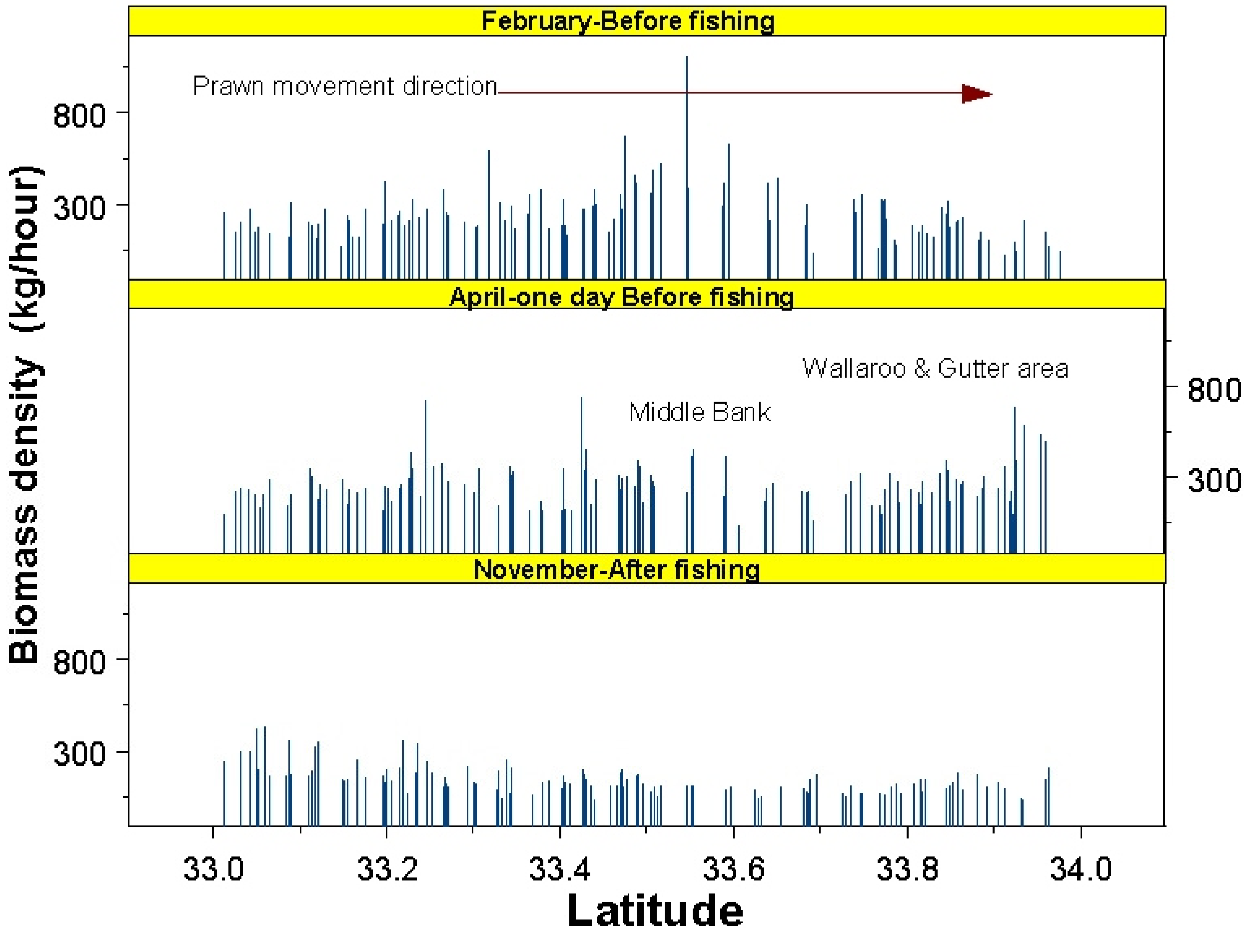


Figure 8.32: Latitudinal changes in prawn biomass density (kg/h) in February, April and November 2001.

Spatial patterns of trawl value ($/h) show substantial changes from February to April (Figure 8.33a & b). There was a large decrease in value at Middle Bank from February to April and an increase in value concentrations and the dispersal of high value over the Wallaroo grounds over the same period.

In November, highest value densities occurred in the northern section of the study area whereas trawl value largely decreased in the areas which were fished (Figure 8.33 c). The density profiles clearly indicate strong changes over latitude with a pronounced homogenisation in value density distribution from April to November at the fished area (Figure 8.34).

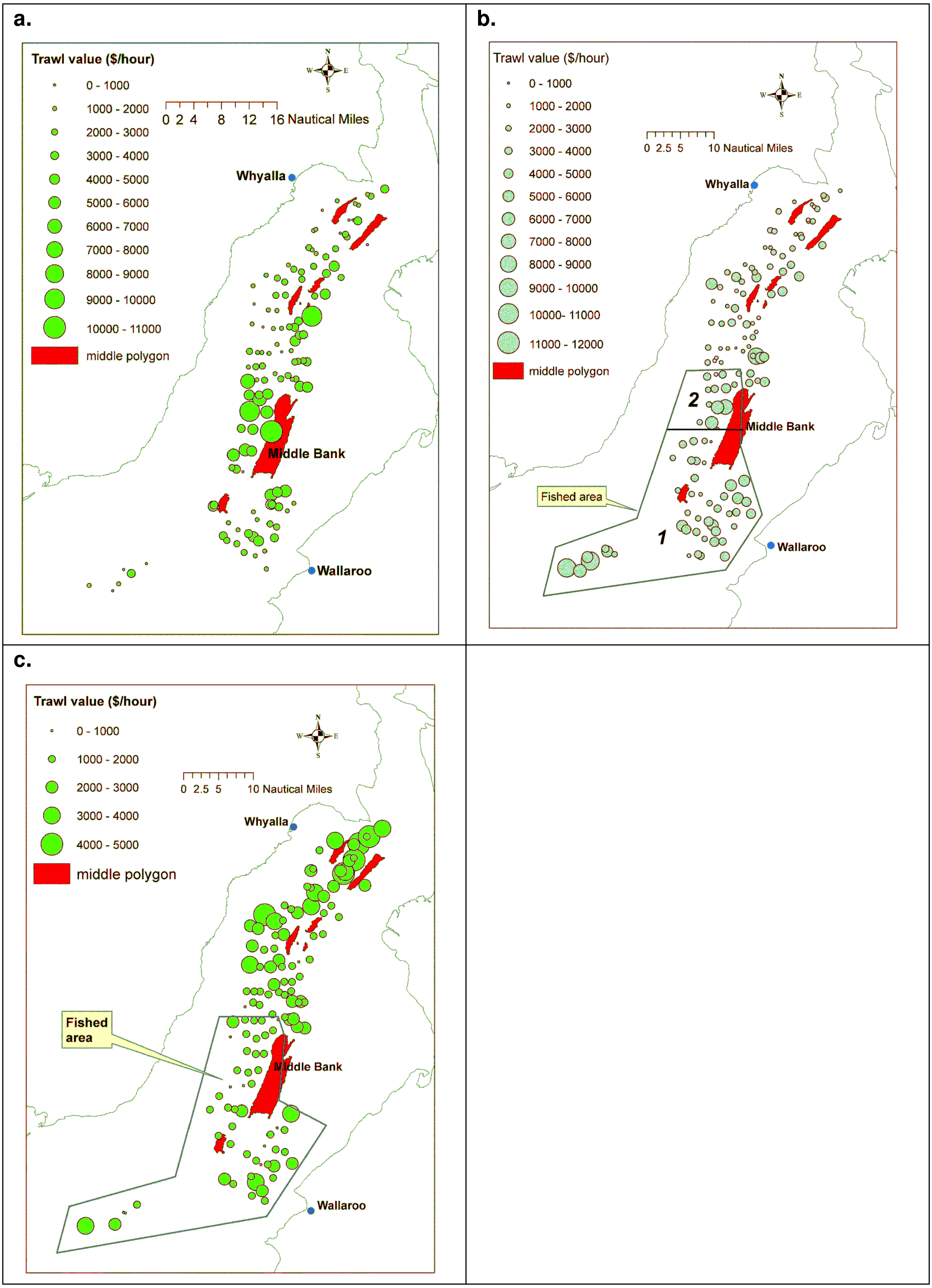


Figure 8.33: Spatial and temporal changes in trawl value ($/h) in Spencer Gulf from February to November 2001-(a) February; (b) April where 1 & 2 are Fished and 3 the unfished regions.

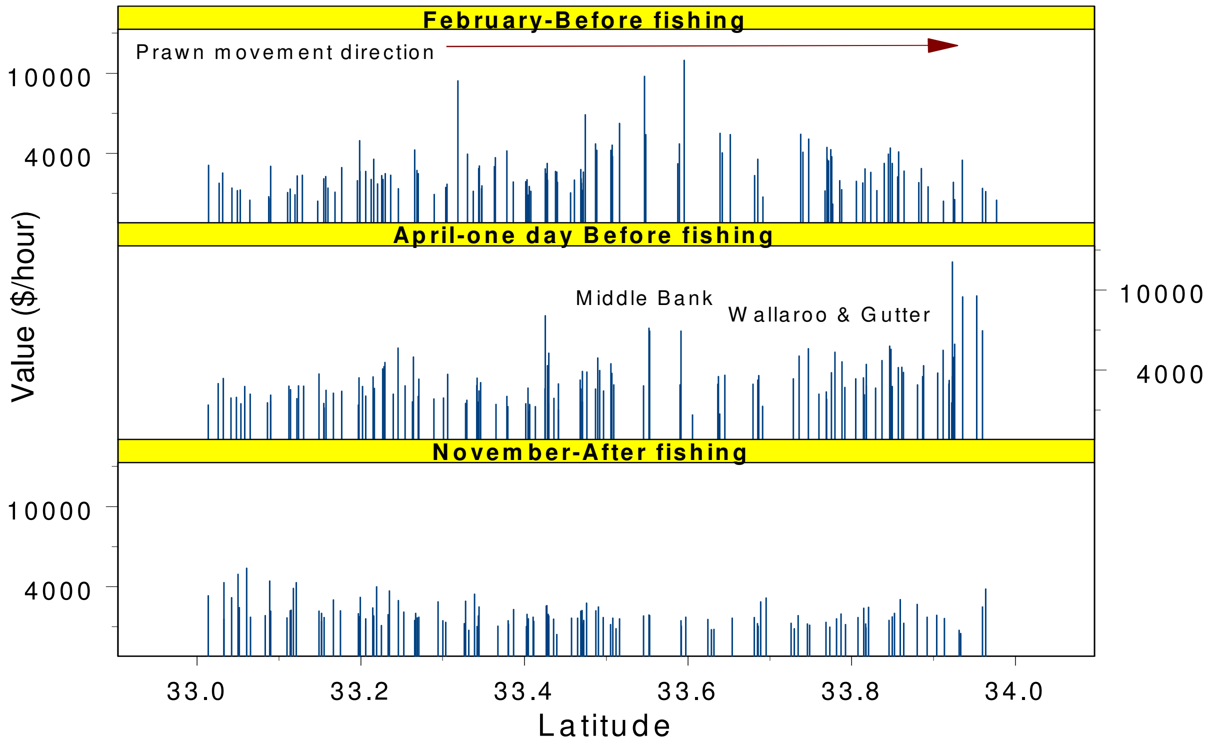


Figure 8.34: Latitudinal changes in trawl value ($/h) in February, April and November 2001.

Prawn density data was square root transformed to homogenise variance in the REML analysis. The objective was to test for Area x Month interaction where change in the response between February and April would be due to prawn movement dispersal. The interaction was significant ($p<0.001$, Wald/df = 22.0) with a sed (standard error of difference) of 6.1 (Figure 8.35). The transformed (square root) mean density increased from 80.3 to 102.7/h from February to April at the Wallaroo and Gutter region; whereas density declined from 126 to 109/h in the northern area over the same period. The interaction is an indicator of the degree of prawn movement dispersal from the northern area to the Wallaroo & Gutter grounds as no fishing took place in the experimental area in February and prior to the trawl survey in April 2001.

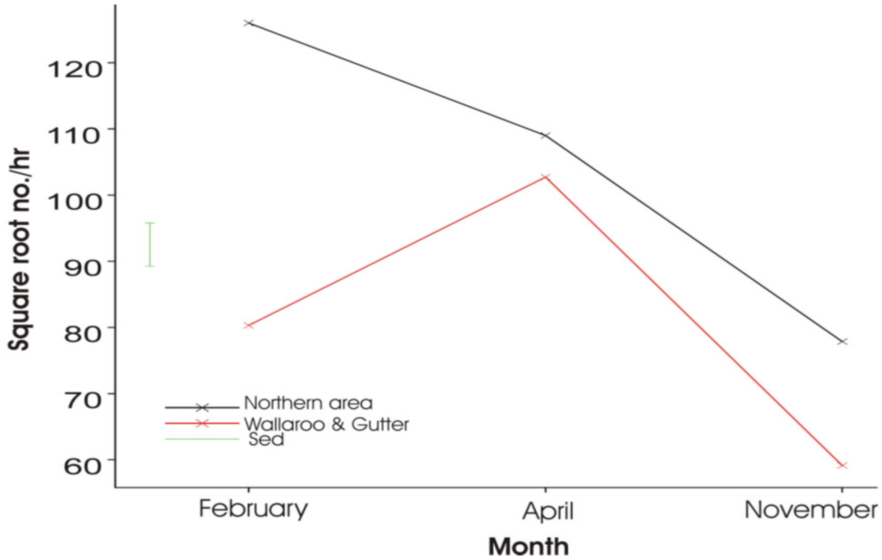


Figure 8.35: REML interaction of mean density (square root no prawns/hr) changes over Area (Wallaroo & Gutter and northern area) in February, April and November 2001.

Mean biomass density (kg/h) largely increased at Wallaroo from February to April; whereas it declined in the northern area. Movement dispersal and the impact of fishing had large effect on density from April to November where a section of the northern area and the entire Wallaroo region was fished. The interaction Month x Area was significant (p<0.000) (Figure 8.36). The results showed a decrease in mean biomass from 266 to 238 kg/h from February to April in the Northern area; whereas in the Wallaroo area the mean biomass increased from 176 to 293 kg/h which was significant (p<0.001). The Month x Area interaction was significant (p<0.001, Wald/df = 20.31, sed = 23.6) due to the large response magnitude in the Wallaroo & Gutter region which was attributable to movement of prawns into the area and biomass growth to larger more valued size.

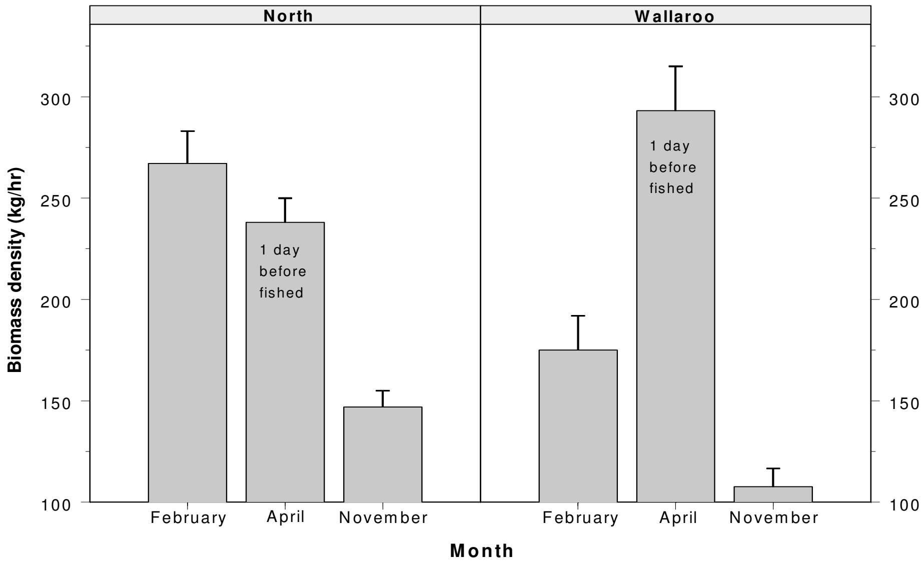


Figure 8.36: Mean biomass density (kg/h) changes and standard errors over Area (Wallaroo & Gutter and northern area) in February, April and November 2001.

The effect of fishing in the fished resulted in a reduction in biomass density and in variance. The decline in variance from April (before fishing) to November (after fishing) at the fished was significantly (P<0.001) larger than the unfished area (Figure 8.37). The results support the hypothesis that fishing reduces both biomass and variance patterns and essentially 'homogenises' an otherwise heterogeneous system by sequentially removing highest prawn density and trawl value concentrations.

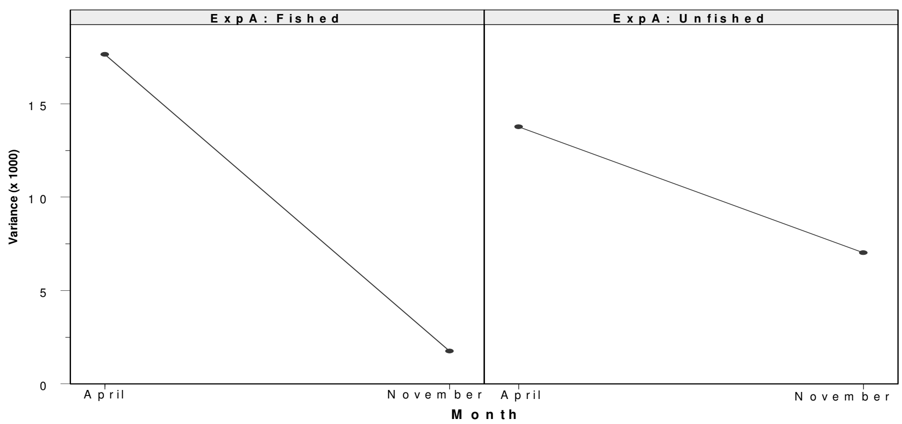


Figure 8.37: Variance changes in biomass density (kg/h) between Fished and Unfished areas before (April) and after (November) fishing in the Northern and Wallaroo areas, 2001.

Mean trawl value ($/h) increased from $2 750 to $2 797/h from February to April in the Northern area; whereas at Wallaroo, the mean increased from $2 628 to $4 648/h and was significant (p<0.001). The Month x Area interaction was significant (p<0.001, Wald/df = 28.9, sed = 310) due to the large response magnitude in the Wallaroo & Gutter region which was attributable to movement of prawns into the area and biomass growth to larger more valued size (Figure 8.38).

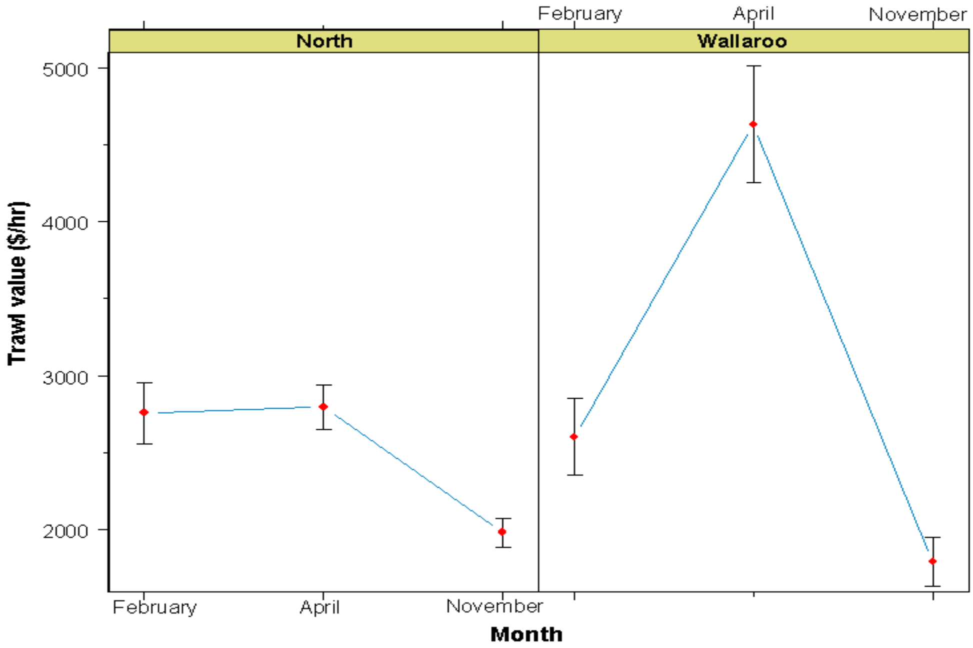


Figure 8.38: Mean value ($/h) changes over Area (North & Wallaroo) in February, April and November 2001 with standard errors.

The population structure of prawns in February 1998 for Wallaroo and Middle Bank shows that prawns were larger at Wallaroo with modal values at 30, 36 and 40 mm CL for males and 34, 42 and 52 mm CL for females (Figure 8.39 and Figure 8.40).

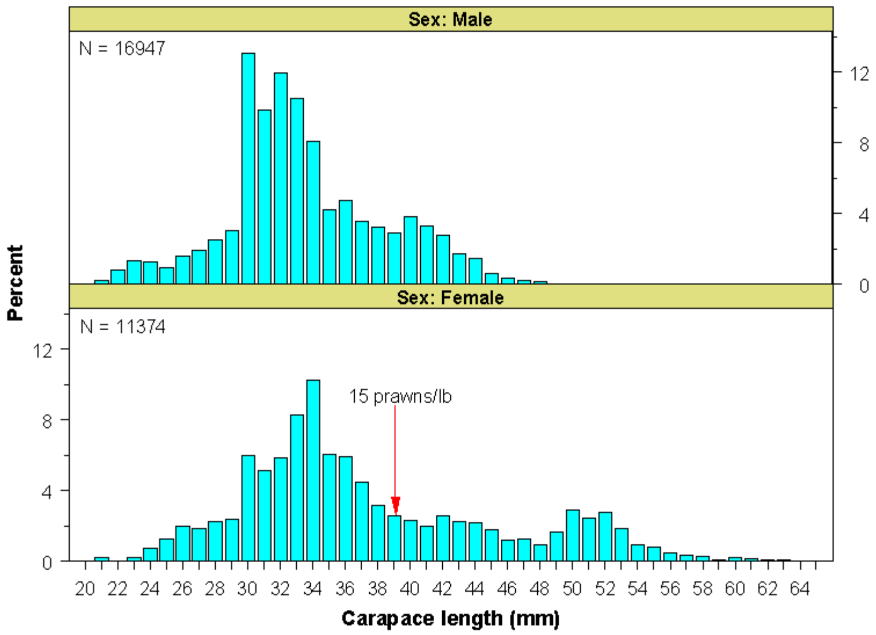


Figure 8.39: Population structure (mm CL) of male and female prawns at Wallaroo in February 1998 pooling sampling sites (N=22).

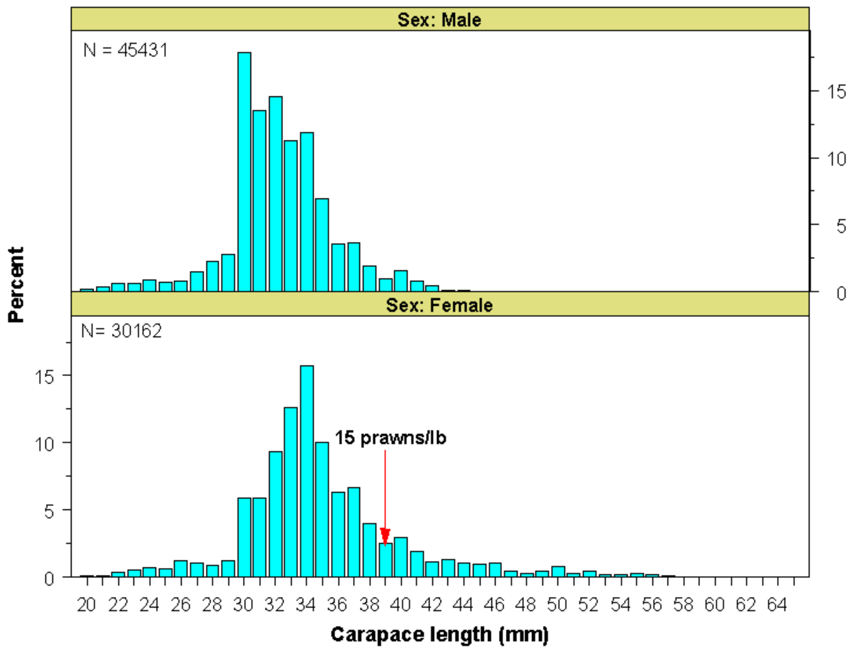


Figure 8.40: Population structure (mm CL) of male and female prawns at Middle Bank in February 1998 pooling sampling sites (N=18).

The pooled size frequencies for each sex were divided by the number of sampling sites to standardise each class interval to no/n mile trawled with data subjected to harvest simulation for determination of trawl value changes from February to May. The simulated trawl value at Wallaroo increased from $440/n mile in February to $671/n mile in May; whereas the value at Middle Bank increased from $1 059/n mile to $1 996/n mile over the same period (Table 8.1). The results show that there was a 50% and 81% increase in trawl value from February to April for Wallaroo and Middle Bank, respectively. The value gain ($/h) was $666/h in April compared to $349/h in March for Wallaroo whereas the value increase at Middle Bank was $2 565/h in April compared to $1 458/h in March.

Table 8.1: Simulation of trawl value change and value increment from February to May 1998 using pooled sites for Wallaroo (N= 22) and Middle Bank (N= 18)

Area	Month	Value ($/nm)	Percent increase	Gain ($/h)
Wallaroo	February	440	0	0
	March	557	26	349
	April	663	50	667
	May	671	52	693
Middle Bank	February	1059	0	0
	March	1545	46	1458
	April	1914	81	2565
	May	1966	86	2721

The results are based on a deterministic simulation of data obtained in the February 1998 survey and do not reflect changes attributable to prawn movement from Middle Bank to Wallaroo (cf. above). However, it is clear that trawl value substantially increases by targeting fishing operations in the April/May period rather than March. An estimate of the value increase to the fishery by targeting operations for 10 days in April/May rather than March was obtained using derived fishing mortalities (F = -0.13 and -0.15/day, see above) and the estimated monthly trawl value increments. The results indicate that there was at least a $3.15 million increase in the value of production by targeting fishing on the prawn population at Wallaroo and Middle Bank in April rather than March.

The population structure of prawns at Wallaroo and Middle Bank in February 2001 was derived using pooled size frequency data from 25 and 21 sampling sites for Wallaroo and Middle Bank, respectively. The pooled size frequencies for each area had similar modes to 1998 but the proportion of smaller prawns was higher in 2001 (Figure 8.41 and Figure 8.42).

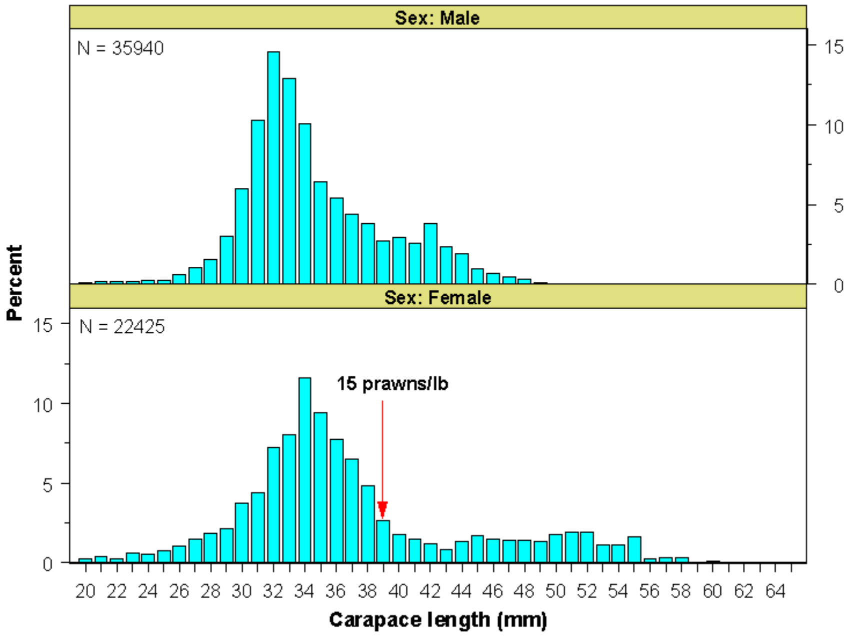


Figure 8.41: Population structure (mm CL) of male and female prawns at Middle Bank in February 1998 pooling sampling sites.

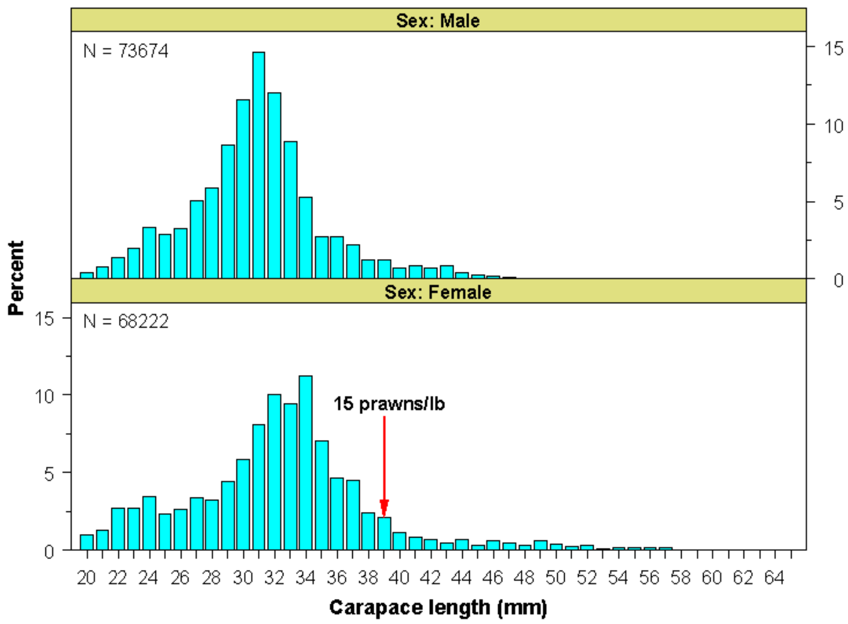


Figure 8.42: Population structure (mm CL) of male and female prawns at Middle Bank in February 2001 pooling sampling sites.

Standardised size frequency data for each site was subjected to the same harvest simulation model used in February 1998. The simulated value changes using all sites were subjected to a non-parametric bootstrap to obtain estimates of mean (se) percentage increase in trawl value from February to May 2001. The mean increase in trawl value was significantly higher in April and May compared to March over both areas (Figure 8.43). The larger means in the Middle Bank area are attributable to the smaller size of prawns and rapid growth in trawl value.

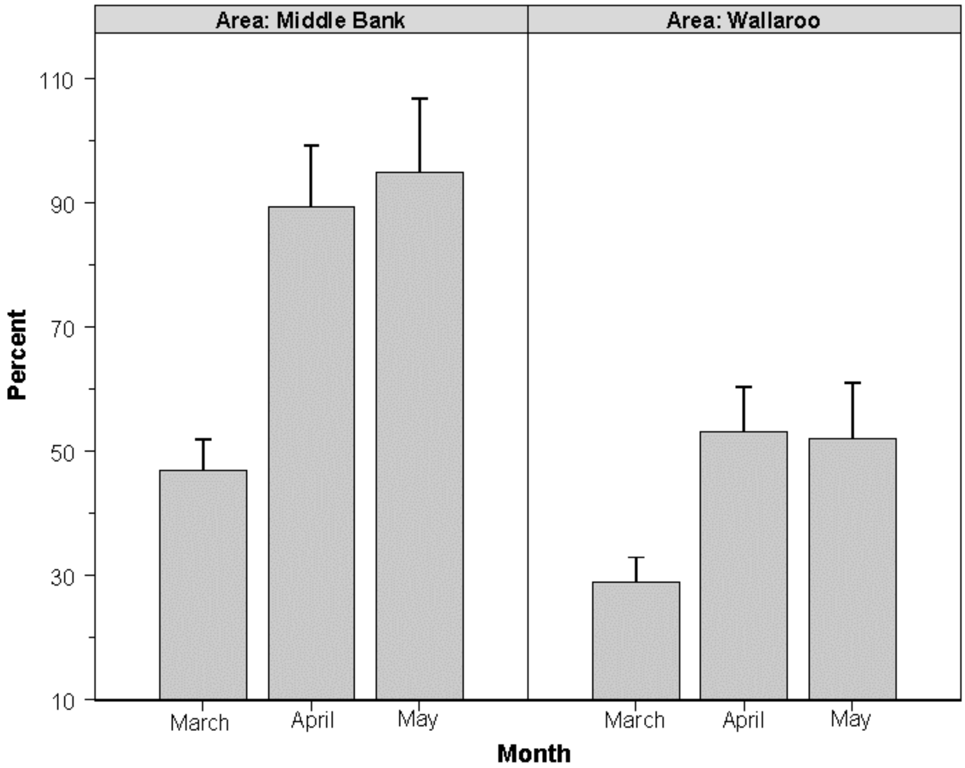


Figure 8.43: Mean percentage (se) increase in trawl value ($/n mile) at Middle Bank and Wallaroo from February to May, 2001. Bootstrap estimates derived from simulated trawl value changes over each trawl sampling site in February, 2001.

The simulation results indicate that trawl value increase is highest in May for the Middle Bank region whereas the value is marginally larger in April at Wallaroo. As in February 1998, there are differences in the population size distribution of prawns within each region, resulting in variations of temporal patterns in trawl value changes. However, the results of both simulations clearly demonstrate that Wallaroo should not be fished in February or March but rather in April to optimise production value.

8.2.4 Discussion

The results from fishery-dependent trawl surveys indicate that large scale movement of prawns takes place from February to April with prawns moving from the northern part of the Gulf to Middle Bank and Wallaroo. The results were corroborated by background investigations of prawn movement. Movement dispersal, prawn growth and fishing have been shown to have large effect on both biomass (kg/h) and trawl value ($/h). The experiments conducted show the benefits of spatial and temporal closures, through increase in trawl value and potential to spread the fleet. It has been demonstrated that high fishing mortalities occur in the fishery resulting in rapid depletion when prawn spatial abundance distribution is low. Experience in the fishery has shown that rapid depletion results in pressure to open more trawl grounds even when sub-populations have not reached optimum harvest size. Allowing prawns to disperse widely over an area has two main advantages: (*i)* it reduces the potential for large scale depletion of sub-populations where prawns aggregate in small sections of grounds (e.g., block 36); (*ii*) increases the potential for the fleet to spread. An 'optimal' closure will therefore, increase catch value, reduce harvest costs and increase the spread of the fleet over many harvesting sequences. Additionally, closure of the Wallaroo region to fishing in March would be of benefit if spawning prawns are spatially concentrated and egg production is high (see Section 8.3).

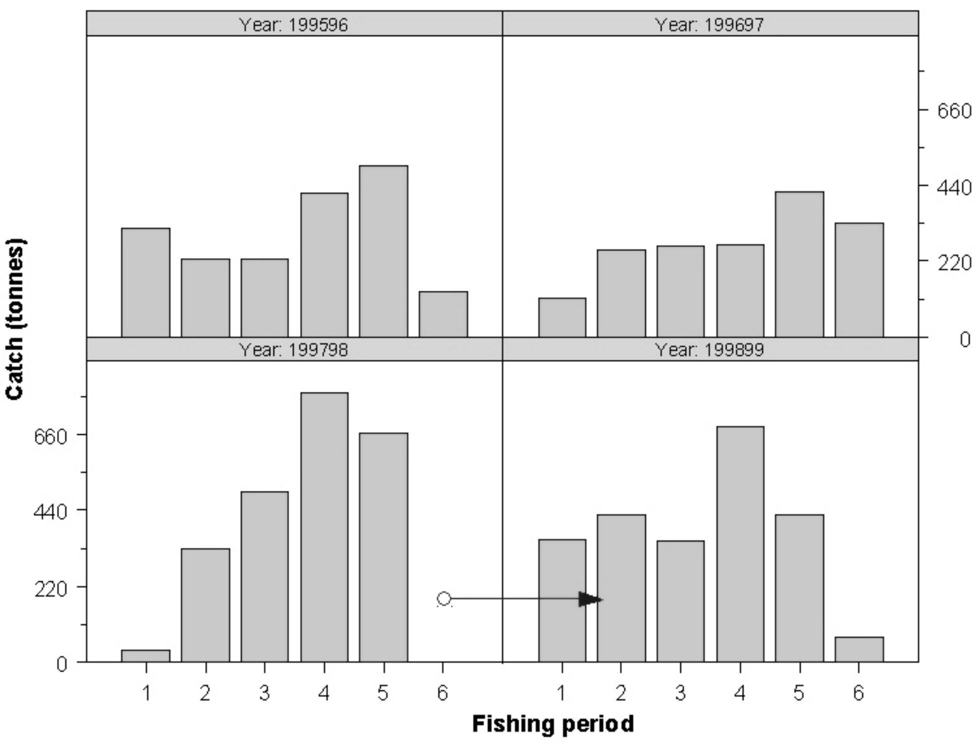


Figure 8.44 Seasonal trends in prawn production over fishing periods from 1995-96 to 1998-99, Spencer Gulf. Fishing periods 1 and 2 are pre-Christmas (November and December), periods 3 to 6 represent March, April, May & June, respectively. The arrow represents effort transfer.

Support for the conclusions is realised by examination of historical prawn production, effort and size composition data. Prawn production (tonnes) and CPUE over each fishing period from 1995-96 to 1998-99 show major changes in seasonal production and CPUE trends (Figure 8.45). **F**ishing takes place over 5 to 6 periods within a year with periods 1 and 2 (termed “pre-Christmas”) occurring in November and December, respectively. Periods 3, 4, 5 and 6 represents the lunar months of March, April, May & June, respectively.

In March 1998, the harvest strategy delayed harvesting at Wallaroo with transfer of effort at that time (period 3) to larger prawns (>70% U15 prawns/lb) in the southern area with view to: (i) optimise biomass growth and the trawl value ($/h) potential of the Wallaroo and Middle Bank grounds for targeted fishing from April (periods 4 to 6, 1997-98); (ii) reduce “waste” by fishing down areas of large prawns (U8 & U10) in the southern area; and (iii) reduce the spatial extent of exploitation in June to optimise catch value increase through premium prices in November/December, (period 1 & 2).

Information obtained from trawl surveys in February, April and May 1998 was used in harvest model simulation of trawl value. Furthermore, monitoring daily catches and depletion signalled that effort (and catch) should be transferred from June to November to optimise demand and value in the pre-Xmas period for cooked prawns and large green grades.

The harvest strategy developed and refined from February to May 1998 resulted in record catches (and CPUE) and the largest size composition (and value) landed by the fleet for 1997-98 with value increase by transferring effort (and catch) from June 1998 to November/December 1998.

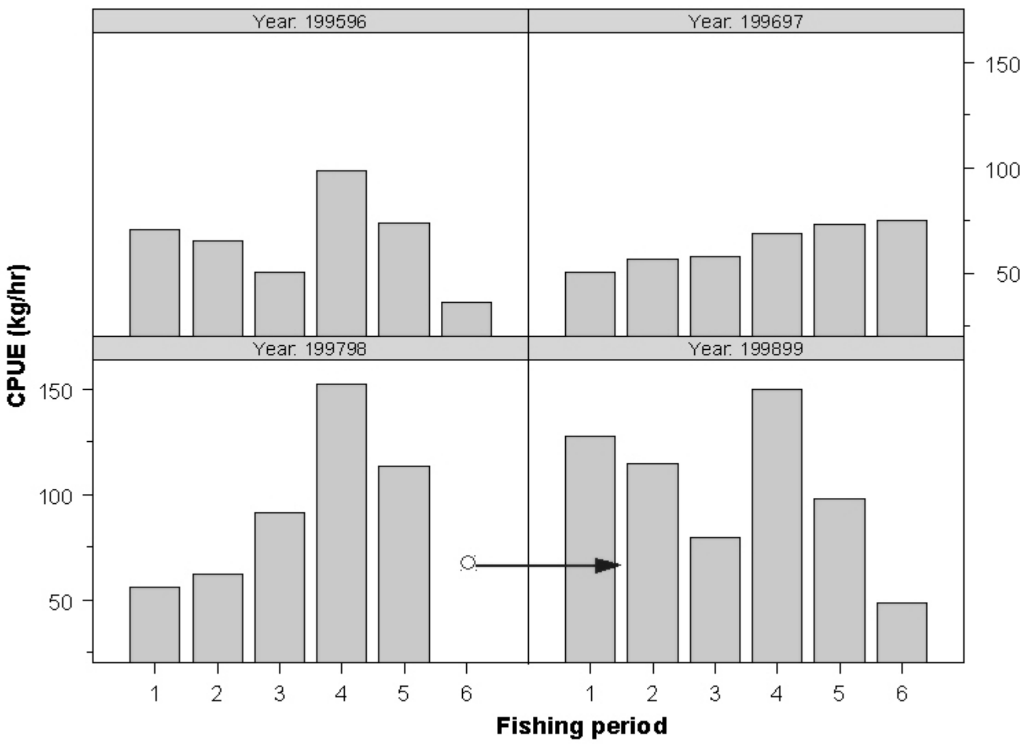


Figure 8.45: Seasonal trends in CPUE (kg/h) over fishing periods from 1995-96 to 1998-99, Spencer Gulf. Fishing periods 1 and 2 are pre-Christmas (November and December), periods 3 to 6 represent March, April, May & June, respectively. The arrow represents effort transfer.

8.3 Spatial density distribution of egg production and simulation of the effect of fishing on egg production

8.3.1 Background

Research has shown that the western king prawns in Spencer Gulf has two spawning peaks in a biological year with data having a good fit (R^2 = 86.5%) to a double Gaussian model, (unpublished). For the Wallaroo region, the first spawning peak occurs from mid-December and the second peak from approximately early-mid March with spawning influenced by water temperature. Juvenile research studies have shown that there are two post-larval settlement peaks to nurseries with the major peak occurring from mid to late April which is expected to be derived from March spawning (unpublished). Hence, intensive fishing in March may have potential to 'structure' post-larval settlement to nurseries and recruitment patterns to grounds if Wallaroo is an important spawning area.

The impact of fishing at Wallaroo on egg production is examined to show the benefits of closure of the region to fishing in March as a risk averse management strategy since the fishery is driven by recruitment where there is a spawner-recruit relationship. A simulation of the effect of fishing a smaller region on total area egg production is examined in realisation that fishing mortality increases with reduction in the size of grounds, spatial aggregation and by targeted fishing on highest trawl value which coincides with highest spatial aggregations of egg production.

8.3.2 Methods

Trawl survey data from April 1998 for the Wallaroo area was subjected to NT6 to estimate egg production from each sampling site (n = 21). NT6 uses input of catch, trawl time, trawl distance, allometry, size frequency samples and size fecundity relationship to derive egg production. Historical fishing mortality estimates were used to simulate the effect of different fishing mortalities on egg production with the region subjected to fishing from Match 1st . Simulations assumed that the initial egg production was 30% lower in March than April. Two simulation models were based on no spawning over the study period while others incorporated a spawning pattern based on a derived Gaussian (bell shaped) distribution which was representative of patterns occurring in the field (unpublished). The simulations are simplified as spawning would have a peak in mid-March.

The spatial distribution of egg density at Wallaroo was mapped to allow a visual comparison of the spatial distribution of trawl value with highest values expected to be sequentially targeted by the fleet. Simulated fishing took place for 5 fishing durations namely 3, 6, 9, 12 and 15 days. The instantaneous fishing mortality rates used as inputs ranged from -0.05 to -0.3/day. Natural mortality was fixed at -0.0023/day and based on background research studies. The initial estimated egg production from each sampling site was used to determine total egg production loss for the Wallaroo region using an exponential decay model described as:

$$A = \sum_{s_1}^{s_{21}} [(N_0 \times \exp(-(F_n + M) \times t_n)]$$

where A = total egg production following fishing and s_1 to s_{21} are stations 1 to 21.
N_0 = Initial egg density (millions x 100/hour) obtained from NT6.
F_n = fishing mortality which ranged from 0.05 to 0.3/day with the mean ± se values obtained from historical estimates for March.
M = natural mortality, fixed at 0.0023/day.
t_n = fishing duration using 3, 6, 9, 12 and 15 days.

Mean historical fishing mortality for the Wallaroo region for March fishing was 0.137 ± 0.035 with a range of 0.1-0.17. The first simulation assumed the fleet would spread and exert the same mortalities over each site which is unrealistic as there would be preference by fishers to target highest value aggregations. The percentage reduction in egg production from the initial size was based on pooling all stations and was estimated as 100* ((E-A)/E) for the different model inputs. The simulation is simplified as fishing mortality is a function of catchability (q) and trawl effort which would increase with reduced stock, reduced trawl area and targeting of high aggregations. Fishing is not a random process and would target highest value areas which are also areas of highest egg production (see above).

A second simulation examined the effect of fishing on egg production when a small area with high egg production (and trawl value) was opened to fishing for 3, 6 and 12 nights. The simulation emulates historical harvest strategies where the northern section of Wallaroo, consisting of aggregations of large prawns, was opened to fishing in March. Egg biomass density decay was simulated by restricting fishing to 6 sites which were situated in the northern section of the Wallaroo grounds. The potential egg production of the reduced fishing area was relatively large owing to the high abundance and larger size of female prawns. The trawl area in the second simulation was reduced by >60%; hence one would expect relatively higher fishing mortalities to be generated than the first simulation owing to reduced area and spatial aggregation. The mortalities used in the second simulation ranged from 0.14 to 0.40 for 3, 6 and 12 fishing nights. The fishing mortalities are high and representative of fleet depletion when small areas are subjected to intensive fishing where high spatial aggregation occurs.

Two additional simulations incorporated spawning from the start of fishing on March 1st to examine the effect of fishing on egg production over 5 fishing durations (viz. 3, 6, 9, 12 and 15 days). A comparison of the impact of fishing on total regional egg production was investigated for: (i) harvesting the whole area (indicated as A and B in Figure 8.47 below); and (ii) fishing a restricted area (A, where there was high egg production). It is noted that a 70 % reduction in the fishing area was expected to double catchability (q) resulting in a doubling of fishing mortality compared to fishing over wider area (see Section 8.1). Data from field studies on female prawn maturation and spawning were used to fit a nonlinear Gaussian or a bell-shape curve to spawning with the spawning constrained to a 28-day duration beginning at March 1st The fitted model resulted in an estimated mean of 14.001 and a standard deviation of 3.067. The fitted values were scaled to 1 to approximate the normal probability density distribution for spawning pattern and are defined as:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

Where x, μ, σ and π are day, mean, standard deviation and pi, respectively.

The normal and cumulative probability distribution of spawning which was derived for each day are illustrated in (Figure 8.46).

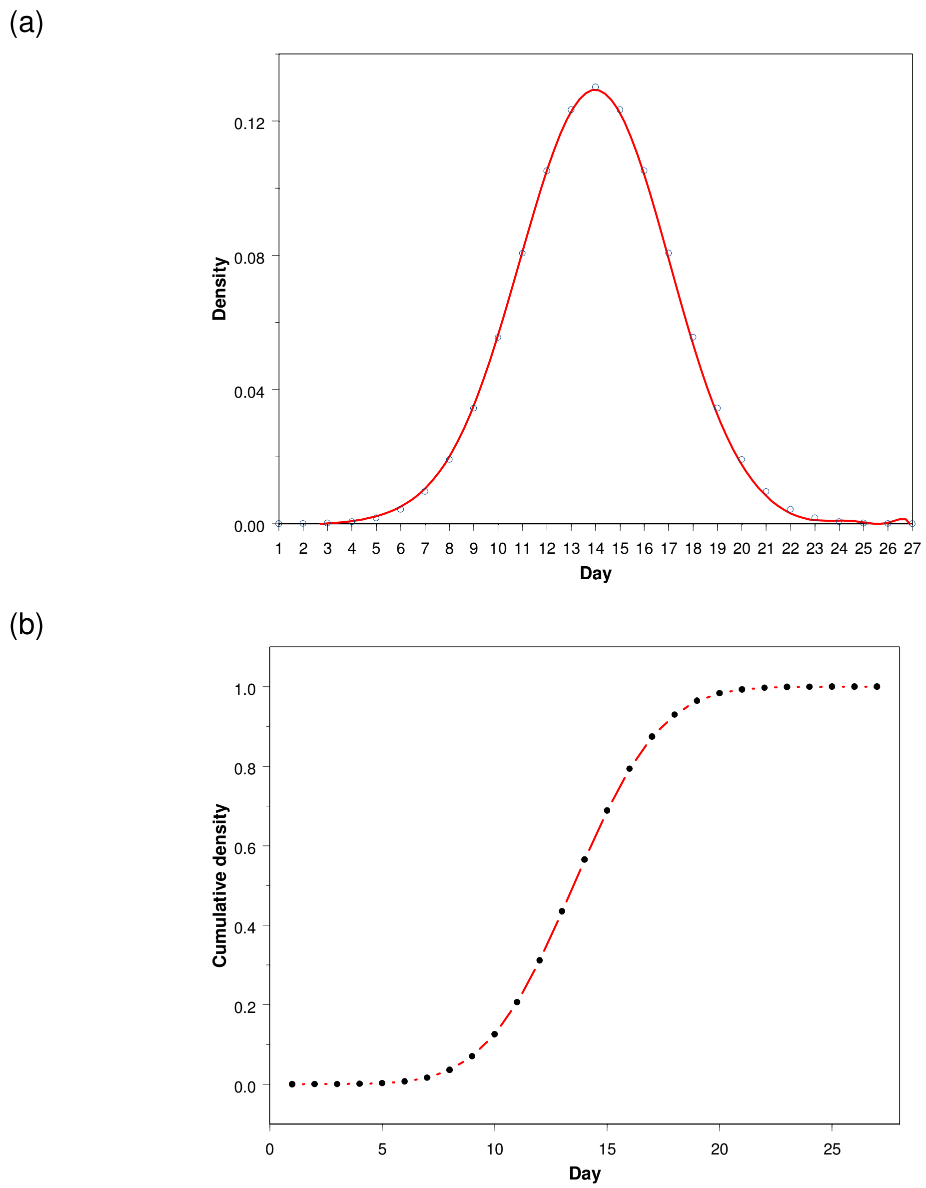


Figure 8.46: Daily spawning patterns used in simulation of egg loss due to fishing-(a) normal density distribution & (b) cumulative distribution of spawning over 28 days beginning March 1.

The cumulative probability distribution curve predicts that at days 3, 6, 9, 12 and 15 about 0.03, 0.7, 7, 31 and 69% spawning occurred, respectively. The deterministic simulation was based on a series of difference equations (21 sites x 15 time intervals x 8 fishing mortalities). Natural mortality was fixed at -0.0023/day and fishing mortalities were F = 0, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35 and 0.4. The general model calculated:

- Potential population fecundity
  $$N_t = N_{t-n} \times (-(F + M) \times t)$$
- Eggs produced each day over different fishing mortalities (above)
  $$I_t = N_t \times f(x)$$
- Accumulated Eggs (E) produced over periods (3, 6, 9, 12 and 15 days)
- The percentage of egg reduction due to fishing compared to zero fishing (F = 0) for each period

The simulation compares the percentage loss of eggs attributable to fishing where prawns were spawning according to a Gaussian distribution.

8.3.3 Results

The spatial distribution of egg density over Wallaroo for April 1998 show high aggregation in the northern section of the region which mirrors the patterns in trawl value and abundance of larger prawn grades, (see above). The first simulation was based on fishing over the whole region (A & B). The second simulation differed to the first in that fishing only took place in the northern section of Wallaroo (A) where the available trawl area was reduced by approximately 78% with egg production highly aggregated in region (Figure 8.47).

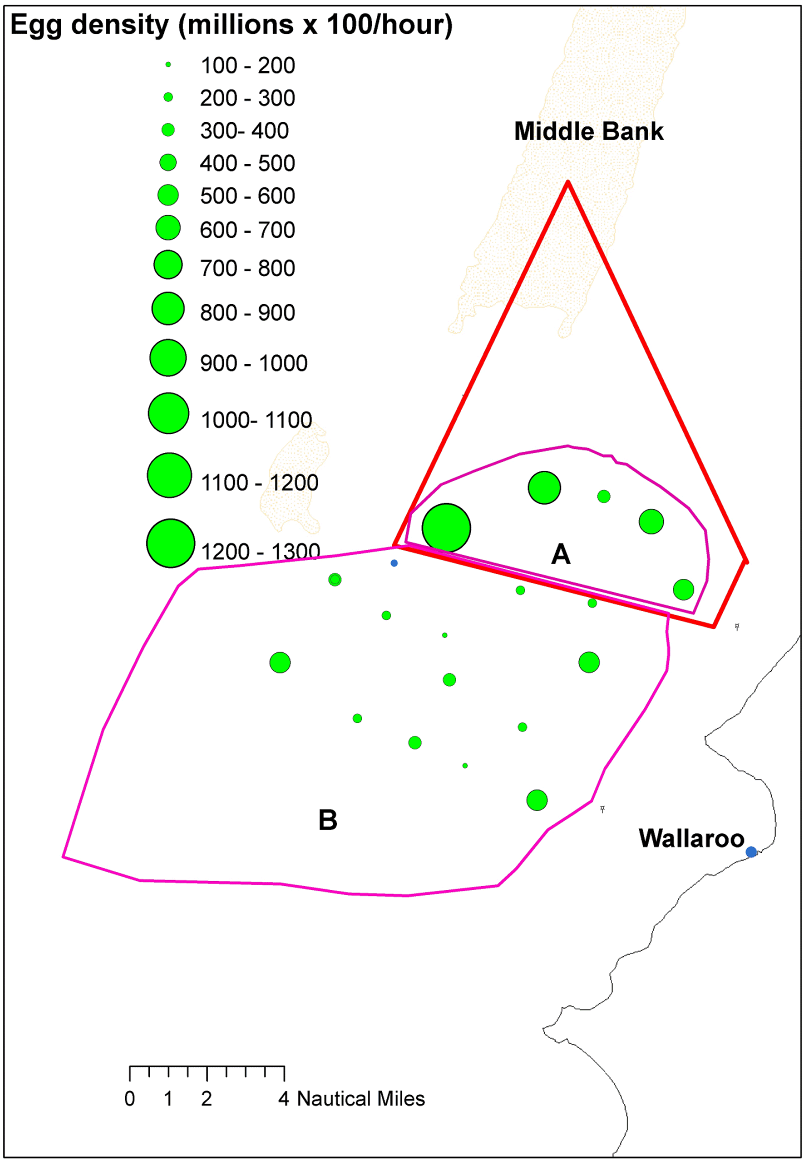


Figure 8.47: The spatial density (millions x 100/h) distribution in prawn egg production based on April 1998 trawl survey where simulated fishing took place in both areas A & B and B. The enclosure for each area represents the amount of trawl area available to trawling.

The simulations assumed that no spawning took place over the simulated time periods with spawning commencing after the 15th March. Hence, intense fishing before spawning would be expected to have large impact on potential egg production. The results of the simulation using areas A & B with no spawning show the reduction in egg production is sensitive to the amount of days fished and fishing mortalities (Figure 8.48). The average mortality estimate (-0.137/day) for 3, 6, 9, 12 and 15 fishing days resulted in reduction of the initial population fecundity by 34.2%, 56.7%, 71.5%, 81.3% and 87.7%, respectively. In the past, >12 fishing days trawl effort were exerted at Wallaroo in February/March. Over the range of historical fishing mortalities (-0.1 to -0.17/day) the simulation indicates that the fleet had the potential to reduce egg production by 71-88% and 81.3% using an average fishing mortality (-0.137/day) for 12 fishing days.

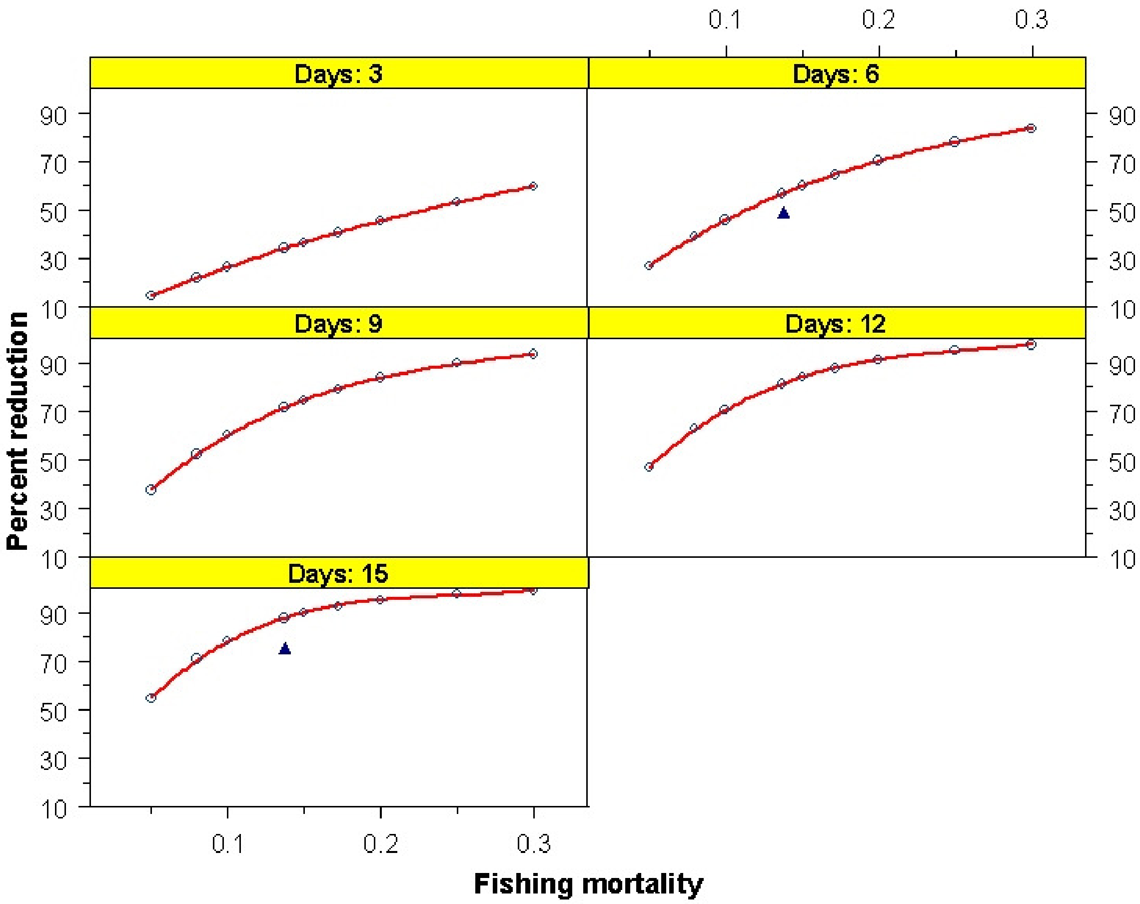


Figure 8.48: Percent reduction in egg production at Wallaroo by fishing in March for 3-15 days with daily fishing mortality rates ranging from 0.1-0.3/day and no spawning. The mean fishing mortality derived from historical data was - 0.14/day and is shown in the second and fifth panels.

The effect of fishing on the total egg production potential by closure of area B and restricting fishing to the smaller area with high aggregation of eggs is of significance. That is, even with a 3-6 fishing days the fleet can remove >28-36% of the total egg production of the region with a fishing mortality of 0.3 (Figure 8.49). A fishing mortality of 0.4 is not unrealistic due to spatial aggregation of prawns, targeted fishing and small area available to fishing. A fishing mortality rate of 0.4 would result in 31.6%, 41.3% and 45.7% loss in total egg production for 3, 6 and 12 days fishing, respectively.

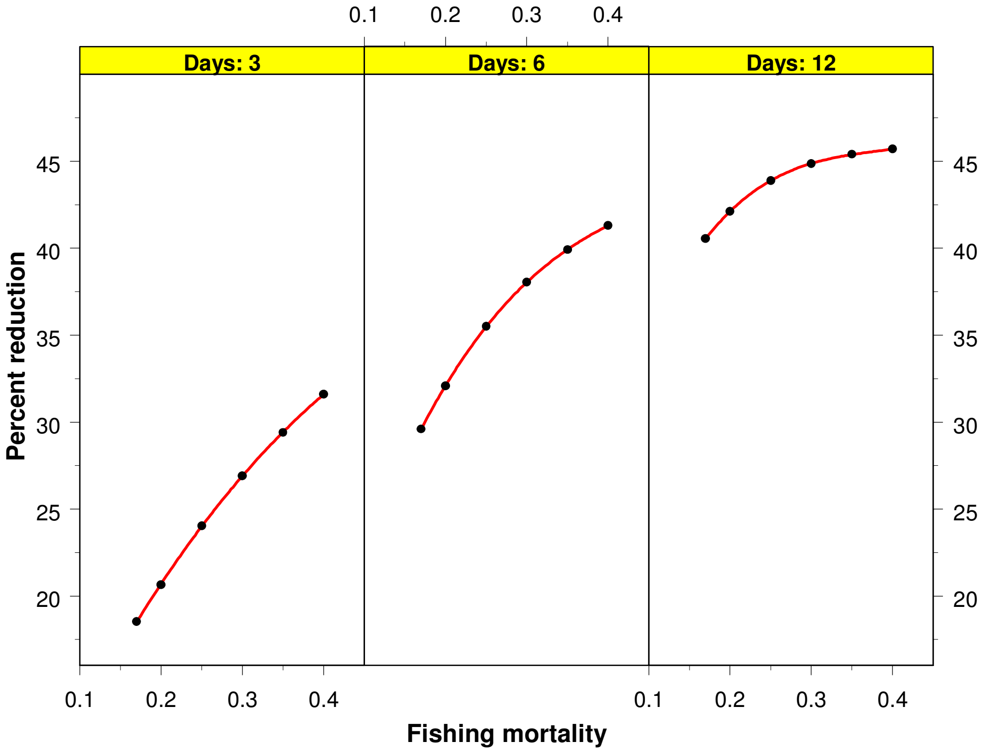


Figure 8.49: Percent reduction in egg production at Wallaroo by fishing in March for 3, 6 & 12 days in a restricted region with high egg production with daily fishing mortality rates ranging from -0.1 to -0.4/day.

The results of the simulations with spawning following a normal (or bell shaped distribution) are of significance as model sensitivity is influenced by fishing mortality, duration of fishing and the amount spawning. When the whole area is opened to fishing the percentage reduction in egg loss compared to no fishing (F = 0) increased from 32.5% to 55.2%, 69.8%, 78.6% and 83.6 % over the 3 days fishing day increments for F = 0.15 (Figure 8.50). With 6-9 days fishing for F = -0.2 the egg production loss ranged from 65.6% to 70%. For the simulation incorporating the spatial closure (or reduced area) the egg losses were lower for the same fishing mortalities (Figure 8.51). However, one would expect catchability (q) would double due to reduced area and targeting on high egg aggregations. Hence, it may not be unrealistic to expect mortalities to range from 0.25-0.3, (c.f. Figures 8.7, 8.11 & 8.12). Even with 6-9 days fishing the fleet has the capacity to reduce the total spawn produced over the periods by 35.3% to -40.2% with F = -0.3/day. The incremental loss in eggs for days >9 are relatively small. However, the simulation indicated that about a 42-43% reduction in spawning eggs would result for 12-15 days fishing in the closed area at F = -0.3 compared to an 87% to 91 % loss at F = 0.2 when the whole area was open to fishing.

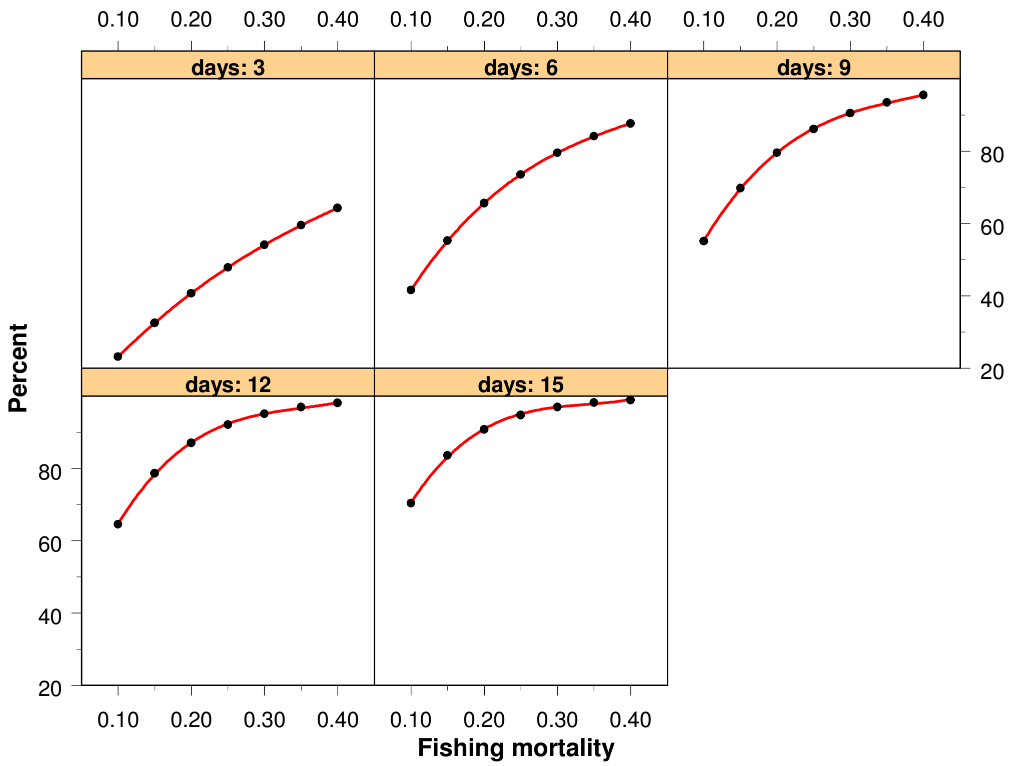


Figure 8.50: Simulation of the percent reduction in egg production at Wallaroo by fishing from March 1st for 3-15 days over the whole region with spawning and fishing mortality values ranging from 0.1-0.4/day and spawning.

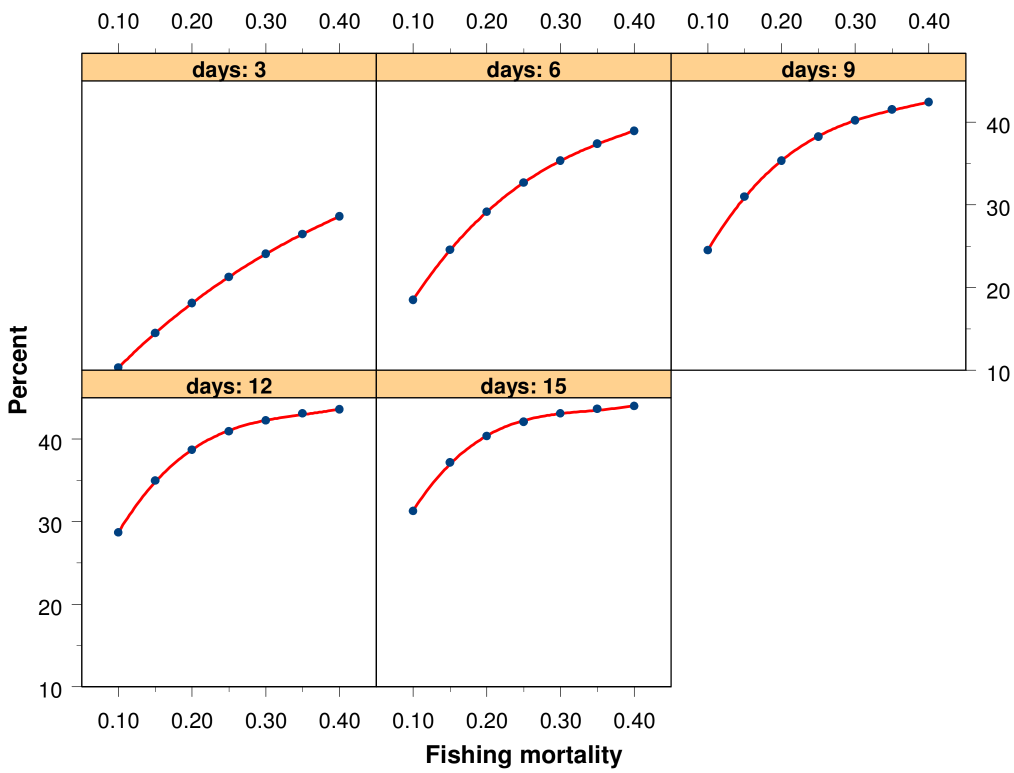


Figure 8.51: Percent reduction in egg production at Wallaroo by fishing from March 1st for 3-15 days over a restricted area (closure) with continuous spawning. Daily fishing mortality rates used in the simulation ranged from 0.1-0.4/day.

8.3.4 Discussion

The amount of eggs produced is dependent on population fecundity, temporal patterns in spawning, when fishing begins, duration of fishing (number days) and fishing mortality rates (F). Western king prawns have two spawning peaks in a biological year. The first occurs in December and the 2nd in March (unpublished). Complete spawning does not take place at once but rather with each spawning sequence approximating a Gaussian distribution. Background data on the assessment of spawning at Wallaroo indicates that peak spawning or egg production occurs around early March but is dependent on water temperature and prawn size.

A simple deterministic simulation was developed to show that fishing mortality rates exerted over a 12 day fishing period from March 1st can have large effect on potential egg production at Wallaroo. Simulation predicts that a fishing mortality rate of -0.10/day would reduce egg production by 71% over a 12 day fishing period. Further, using average historical fishing mortality (-0.137/day) would reduce the 'spawn' at Wallaroo by about 81% for 12 fishing days when there is negligible spawning. The duration of fishing has large effect on the amount of eggs produced- 3 days fishing reduces eggs by 34% compared to 81% for 12 fishing days However, the reductions would be underestimated if fishing was targeted to spatial aggregations of high egg production. The effect of fishing on total egg production at Wallaroo with a large section closed to fishing resulted in a large loss in egg production, even with 3-6 days of fishing, with fishing mortality > -0.3/day. High fishing mortalities would be generated by reduced trawl area available and preference of fishers to target highest value aggregations which mirror egg production aggregations.

Simulations which incorporated continuous spawning, showed that: with a reduced fishing duration (6-9 days), a minimum expected fishing mortality (i.e. F= -0.3/day) for a reduced area has the potential to reduce egg production by 35-40%. When the whole region is opened to fishing for >6 days in March, the reduction in spawning would be at least 70% using the expected fishing mortality estimates. Clearly, the temporal spawning pattern, fishing mortality and duration of fishing have large impact on egg production. The closure of Wallaroo to fishing in March may be considered as a risk-averse strategy for minimizing recruitment decline in the Spencer Gulf fishery where an asymptotic spawner-recruit relationship exists. The results demonstrate that economic and biological benefits are achieved by eliminating and/or reducing fishing in Wallaroo in March. The results indicate that fishing Wallaroo in March, when annual recruitment declines, poses a risk to fishery sustainability and profitability. A harvest strategy based on limited fishing (e.g., 3 days) in March would involve spatial closures to protect sub-optimal prawns but would result in targeting the highest egg production, reduce the spread potential of the fleet and may not result in economic gain. When it is known that the potential spawning stock is large, opening Wallaroo for a limited period in March could be considered but requires an objective assessment. Information required for decision making should include data from trawl surveys and tagging (prawn movement dispersal). Ideally, the simulation models should be enhanced to incorporate stochastic variation using real time survey data. Simulation models require enhancement with more reliable information relating to important input parameters including reproductive maturation, population fecundity, movement dispersal, vulnerability, catchability and expected fishing mortalities).

Management may need to consider the benefits of commissioning fishery-independent surveys in March over selected sites in the Wallaroo area to refine of harvest strategies. A less costly alternative would be the development of harvest simulation models and decision frameworks incorporating data collected in the past (e.g., spawning patterns etc), cost-effective assessment of the amount of spawning and population fecundity and daily depletion by the fleet.

9 Conclusions

There is a need for all South Australian prawn and blue-swimmer crab fisheries to move towards a more reliable, accurate and cost-effective collection of fishery-independent and dependent data, and for adaptive real-time management involving government and industry. The study has resulted in the development of a 'state-of-the-art' Oracle database system which has allowed diverse data to be analysed and used in the stock assessment and management of the fisheries. The focus of the research was on prawn fishery spatial processes, especially those based on fishery-independent trawl survey assessments, mark-recapture studies and analysis of commercial catch and effort data. The integrated database system developed for the Spencer Gulf and West Coast fisheries needs to incorporate additional data on female prawn maturation/spawning, environmental variation and inshore post-larval and juvenile prawn temporal abundance trends. Such a system will provide a most powerful tool for research and management of the prawn fisheries, as well as, provide a greater understanding of the factors which influence recruitment and fishery production.

The integration of databases to provide information on vital fishery performance indicators and the development of optimal harvesting strategies resulting from the research has resulted in substantial economic gain to industry, as demonstrated in the report

The databases developed in the project and associated analytical applications have resulted in a suite of tools for the rapid or real-time assessment of the health (e.g., recruitment levels) or sustainability of the fishery. It must be realised that real-time management should not be considered as a tool to increase catch or effort when stocks are low. On the contrary, real-time adaptive management in the Spencer Gulf prawn fishery has resulted in decreased trawl effort and a substantial increase in the size of prawns captured The amount of effort applied or catch is dependent on both recruit and spawner levels.

Modern telecommunication (in particular the inexpensive CDMA) and Internet technologies provide a powerful basis for the exchange and communication of data with the fleet and for the application of real-time management.

Decision frameworks for fishery management need an objective basis requiring reliable data, rigid analysis and modelling frameworks. The research has highlighted "gaps" in knowledge and the need for additional research which should be prioritised. In particular, there is a need to enhance the Oracle database systems for South Australian prawn fisheries, to conduct field studies in order to determine prawn catchability (availability), as well as additional prawn movement studies for the enhancement of harvest models and stock assessment within a risk framework. The study of the relationship between spawners and recruits (SRR) and the influence of environmental variation on recruitment is of paramount importance to fishery management. For Spencer Gulf, there is a need to update the 1995 study of spawner-recruit and the influence of environmental variation on recruitment using the extensive fishery independent data collected (1982-2004) and the database systems developed by the FRDC research project.

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11 Appendices

Appendix 1: Example of fisher real-time data transfer from sea to shore using CDMA

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1			REG			RATE	RATE	NO PRN	BKT	SAMPLE	NUMBER	MALE	NUMBER	FEMALE		
2	VESSEL	DATE	CODE	STN	MINS	KG/MI	LB/MI	PER BKT	KG	KG	MALE	KG	FEMALE	KG	TIDE	TEMP
3	EVELYN	21/11/2003	STCH	ST2	30	0.5	1.2	134	6.70	6.70	89	3.80	45	2.9	AT	19.00
4	EVELYN	21/11/2003	STCH	ST1	30	0.3	0.6	114	7.00	7.00	54	2.30	60	4.7	WT	19.00
5	EVELYN	21/11/2003	GUTT	6D1	30	0.3	0.8	268	7.00	7.00	180	3.90	88	3	WT	19.00
6	EVELYN	21/11/2003	GUTT	6C	30	0.9	2.1	188	6.70	6.70	82	2.40	106	4.3	WT	19.00
7	EVELYN	21/11/2003	GUTT	5C	30	0.7	1.6	184	6.60	6.60	81	2.40	103	4.2	WT	18.50
8	EVELYN	21/11/2003	GUTT	8C	30	0.6	1.4	189	6.80	6.80	106	2.90	83	3.9	WT	19.00
9	EVELYN	21/11/2003	GUTT	9C	25	1.4	3.2	166	6.50	6.50	74	2.30	92	4.2	WT	19.00
10	EVELYN	21/11/2003	GUTT	9B	30	0.5	1.2	191	7.40	7.40	102	3.00	89	4.4	AT	19.00
11	EVELYN	21/11/2003	GUTT	8B	30	0.2	0.5	218	6.40	6.40	136	3.40	82	3	AT	19.00
12	EVELYN	21/11/2003	GUTT	8A	30	0.1	0.3	110	3.70	3.70	43	1.30	67	2.4	WT	19.00
13																
14	EVELYN	22/11/2003	SWAL	32	25	0.4	0.8	124	6.90	6.90	68	3.20	56	3.7	AT	19.00
15	EVELYN	22/11/2003	SWAL	31	30	0.9	2.0	148	7.10	7.10	75	2.90	73	4.2	AT	19.50
16	EVELYN	22/11/2003	WAL	12	30	0.7	1.4	192	6.60	6.60	121	3.60	71	3	AT	19.50
17	EVELYN	22/11/2003	WAL	19	30	0.5	1.2	216	6.60	6.60	151	4.10	65	2.5	WT	19.00
18	EVELYN	22/11/2003	WAL	5	30	0.7	1.4	198	6.90	6.90	107	3.20	91	3.7	AT	19.00
19	EVELYN	22/11/2003	WAL	21	32	0.4	1.0	147	6.60	6.60	57	2.00	90	4.6	WT	19.50
20	EVELYN	22/11/2003	WAL	6	30	0.2	0.4	110	5.80	5.80	33	1.40	77	4.4	ST	19.50
21	EVELYN	22/11/2003	WAL	1	30	1.1	2.4	192	6.90	6.90	130	4.20	62	2.7	WT	19.50
22	EVELYN	22/11/2003	WAL	17	30	0.3	0.6	195	7.10	7.10	117	3.60	78	3.5	AT	19.50
23	EVELYN	22/11/2003	WAL	20	30	1.5	3.2	193	6.50	6.50	134	3.90	59	2.6	WT	19.50
24	EVELYN	22/11/2003	WAL	2	30	2.4	5.4	203	7.20	7.20	140	4.50	63	2.7	WT	19.50

Appendix 2: Catch and Effort daily prawn fishery logbook developed and tested for the project.

SOUTH AUSTRALIAN PRAWN FISHERY DAILY FISHING LOG SPENCER GULF

LICENCE NO:	DATE: / /	FISHING PERIOD: from / / to / /
VESSEL NAME:	SKIPPER NAME	

SHOT NO.	BLOCK NO.	START TIME	FINISH TIME	TRAWL MINS	CATCH (KG)	DEPTH (Metre)	MIDPOINT OF TRAWL SHOT		BY CATCH SPECIES AND AMOUNT CODE DISCARDS	COMMENTS
							LATITUDE	LONGITUDE		
1		:	:				. .	. .		
2		:	:				. .	. .		
3		:	:				. .	. .		
4		:	:				. .	. .		
5		:	:				. .	. .		
6		:	:				. .	. .		
7		:	:				. .	. .		
8		:	:				. .	. .		
9		:	:				. .	. .		
10		:	:				. .	. .		
11		:	:				. .	. .		
12		:	:				. .	. .		
13		:	:				. .	. .		
14		:	:				. .	. .		
15		:	:				. .	. .		
16		:	:				. .	. .		
17		:	:				. .	. .		
18		:	:				. .	. .		
AVERAGE TRAWL SPEED: . (Knots)			TOTAL							

NUMBER CARTONS:	CARTON WEIGHT: . KG

Note: The discarded bycatch species & amounts code and comments column is NOT mandatory
The mid-point of the trawl shot is mandatory and required from plotter at least 3 times through each night preferably at start, mid and last shot.

PRAWN SIZE GRADES (NO/LB)

GRADE												TOTAL
KG												

BYCATCH:	CALAMARY: . KG	BUGS: . KG		WATER TEMPERATURE: . °C

** Comments columns are voluntary & all other part of daily logbook sheet is mandatory under S.A Government Legislation

Appendix 3 Government reporting examples

Appendix 3a: Use of prawn fishery catch and effort daily logbook and fishery-independent trawl survey data.

S A R D I

A preliminary Report to PIRSA Fisheries on the status of the Spencer Gulf prawn fishery, 2002/2003

Neil Carrick
November 2003

1. Fishery catch and effort trends, 2002/2003.

The Spencer Gulf fishery is based exclusively on the western king prawn (*Melicertus latisulcatus*). Provisional information on production statistics indicates that the landed catch in 2002/2003 was 1,489.5 tonnes for 51 nominal fishing days, which was equivalent to 70.4 effective effort days. The nominal effort in 2002/2003 was 18,904 hours. The annual nominal catch rate was 75.82 kg/h and the adjusted catch rate was 54.94 kg/h. Production has declined by about 31.7 % compared to 2001/2002. Table 1 provides a summary of seasonal catch and nominal catch and effort trends with the largest catch and catch rate occurring in period 5. The fleet were restricted to fishing north of Plank light and Fishing was delayed in the Wallaroo area to maximise value of catch and control exploitation.

Table 1: Summary of Spencer Gulf prawn fishery catch and effort, 2002/2003.

Period	from	to	days	kg	hours	cpue
1	5/11/2002	10/11/2002	6	190568	1904.6	97.1
2	29/11/2002	11/12/2002	11	235535	3328.3	68.7
3	4/03/2003	8/03/2003	5	107031	1776.9	59.2
4	29/03/2003	9/04/2003	10.5	298326	4058.2	68.5
5	29/04/2003	10/05/2003	11.5	477606	4708.1	99.7
6	28/05/2003	3/06/2003	7	180453	3127.9	54.8
		Year total	51	1489519	18904.0	75.8

2. Prawn size composition

The size composition of catch based on >89 % of the fleet landings show that 25.9 % were in the U10 (no/lb, head on) category with 40.3, 22.6, 4.4, 0.2 and 6.6 % in the 10/15, 16/20, 21/30, >30 and Soft & Broken grades, respectively.

3. Assessment of recruitment to grounds.

Fishery-independent survey sampling indicated a significant decline in recruitment and the biomass density of stock in 2003. An integrated Oracle database for fishery-independent trawl surveys was developed through funding support from FRDC. Detail of the system will be incorporated in the final 2002/2003 stock assessment report. ***Analysis showed that the recruitment index in 2002/2003 was 31.3 and lower than the limit of 35 set in the fishery management plan***. The decrease in landings was directly attributable to recruitment decline. The decline in recruitment was reported to industry and the FMC in March 2003 and consequently harvesting strategies adapted were designed to control exploitation and ensure that sufficient spawning stock is available for the November 2003-March spawning season. Further research is being focused to modelling the relationship between spawners and recruits and the influence of environmental variation.

All fishery performance indicators except for the recruitment index were better than the targets set in the management plan.

4. Virgin spawning biomass and exploitation.

The virgin spawning biomass and exploitation levels cannot be estimated until all catch and effort data from fishing in November/December 2003 are entered into the PIRSA/SARDI database system and subsequently analysed to estimate parameters.

5. Important issues

New logbooks were introduced in 2002 and an Oracle catch and effort database system was developed in Oracle. There have been a number of problems relating to data entry of fishers logbook forms and in producing output files. The PIRSA/SARDI Oracle database system needs to be enhanced in 2004 to allow data files to be generated without “gaps” in data and without appending each fishing unit to generate data files. The final report on the fishery, due in March 2004, is dependent on data entry and validation of fishers’ logbook data (see above) and enhancement of the PIRSA/SARDI database system.

Comparison of a seven year time series of November fishery-independent survey data showed that the biomass density in 2003 was at least 50 % lower than the average of previous six years. Furthermore, research indicated that insufficient spawning had not taken place in October and November and accordingly PIRSA Fisheries were advised that constraints be placed on the effort and catch.

It is advised that a major research priority should be to obtain reliable seasonal vulnerability (availability) which would involve “stand-alone’ trawl sampling studies commonly referred to in the fisheries and biometrics research literature as ‘depletion studies’. Furthermore, a research and industry based tool for real-time measurement of the reproductive maturation and spawning status of stock needs to be developed and implemented. The latter would allow greater scope for modelling reproductive depletion and lead to refinement of harvest strategies.

The new logbook system and database has incorporated retained bycatch (or by product), which will be reported in the final stock assessment report (March 2004).

Appendix 3b: Closure Notice

To: Jon Presser (Principal Manager, PIRSA Fisheries)
R.Haynes (Wallaroo Radio Base)
SPG & WCPFGA

PRAWN FISHERIES MANAGEMENT COMMITTEE
SPENCER GULF HARVESTING STRATEGY
For the period 2030 hr 17/12/2003 to 0600 hr 24/12/2003 (7 nights)

The committee agreed that fishing in December 2003 be limited to 7 nights with 5 nights in the northern area and Wallaroo and the last 2 nights in the southern area (see below). The committee agreed to monitor the size of prawns daily, and accordingly recommend change to closure lines if required. Maps of northern and southern area closures are attached. Research has demonstrated that the spawning stock level is relatively low and accordingly the strategy adapted aims to ensure the fishery is sustainable

A. NORTHERN AREA

(i) 2030 hr 17/12/2003 to 0600 hr 20/12/2003 (3 nights)

Trawling is prohibited north of the following closure index points:

1. 33° 16.0' S, 137° 50.0'E (East shore)
2. 33° 09.0' S, 137° 41.0'E
3. 33° 16.0' S, 137° 33.0'E
4. 33° 21.0' S, 137° 32.5'E
5. 33° 25.0' S, 137° 29.0'E
6. 33° 25.0' S, 137° 21.0'E (West shore)

(ii) 2030 hr 20/12/2003 to 0600 hr 22/12/2003 (2 nights)-buffer line

Trawling is prohibited north of the following closure index points:

1. **33° 16.2'** S, 137° 50.0'E
2. **33° 09.2'** S, 137° 41.0'E
3. 33° 16.0' S, **137° 33.2**'E
4. 33° 21.0' S, **137° 32.7**'E
5. 33° 25.0' S, 137° 29.0'E
6. 33° 25.0' S, 137° 21.0'E

(iii) 2030 hr 17/12/2003 to 0600 hr 22/12/2003 (5 nights)-Stones box

Trawling is prohibited within the following closure index points:

1. 33° 22.0' S, 137° 34.0'E
2. 33° 22.0' S, 137° 37.0'E
3. 33° 30.0' S, 137° 37.0'E
4. 33° 30.0' S, 137° 34.0'E then back to
1. 33° 22.0' S, 137° 34.0'E

(iv) 2030 hr 17/12/2003 to 0600 hr 24/12/2003 (7 nights)-Broughton closure

Trawling is prohibited within the following closure index points:

1. 33° 19.0’ S, 137° 51.0’E (East shore)

2. 33° 22.3’ S, 137° 47.3’E (Wood P)
3. 33° 37.0’ S, 137° 33.0’E (Middle Bank)
4. 33° 46.0’ S, 137° 44.0’E (near Tickera)

B. SOUTHERN AREA

(i) 2030 hr 17/12/2003 to 0600 hr 22/12/2003 (5 nights)

Trawling is prohibited within the following closure index points:

1. 33° 38.0’ S, 137° 13.0’E (near Shoalwater Pt)
2. 33° 45.0’ S, 137° 24.0’E
3. 33° 52.0’ S, 137° 17.0’E
4. 33° 55.0’ S, 137° 20.0’E
5. 34° 02.0’ S, 137° 01.0’E
6. 34° 00.0’ S, 136° 59.0’E
7. 34° 06.0’ S, 136° 46.0’E
8. 33° 57.0’ S, 136° 33.0’E (Arno)

(ii) 2030 hr 22/12/2003 to 0600 hr 24/12/2003 (2 nights)

Trawling is prohibited within the following closure index points:

1. 34° 08.0’ S, 137° 35.0’E (East shore)
2. 34° 08.0’ S, 136° 49.0’E
3. 33° 57.0’ S, 136° 33.0’E (Arno)

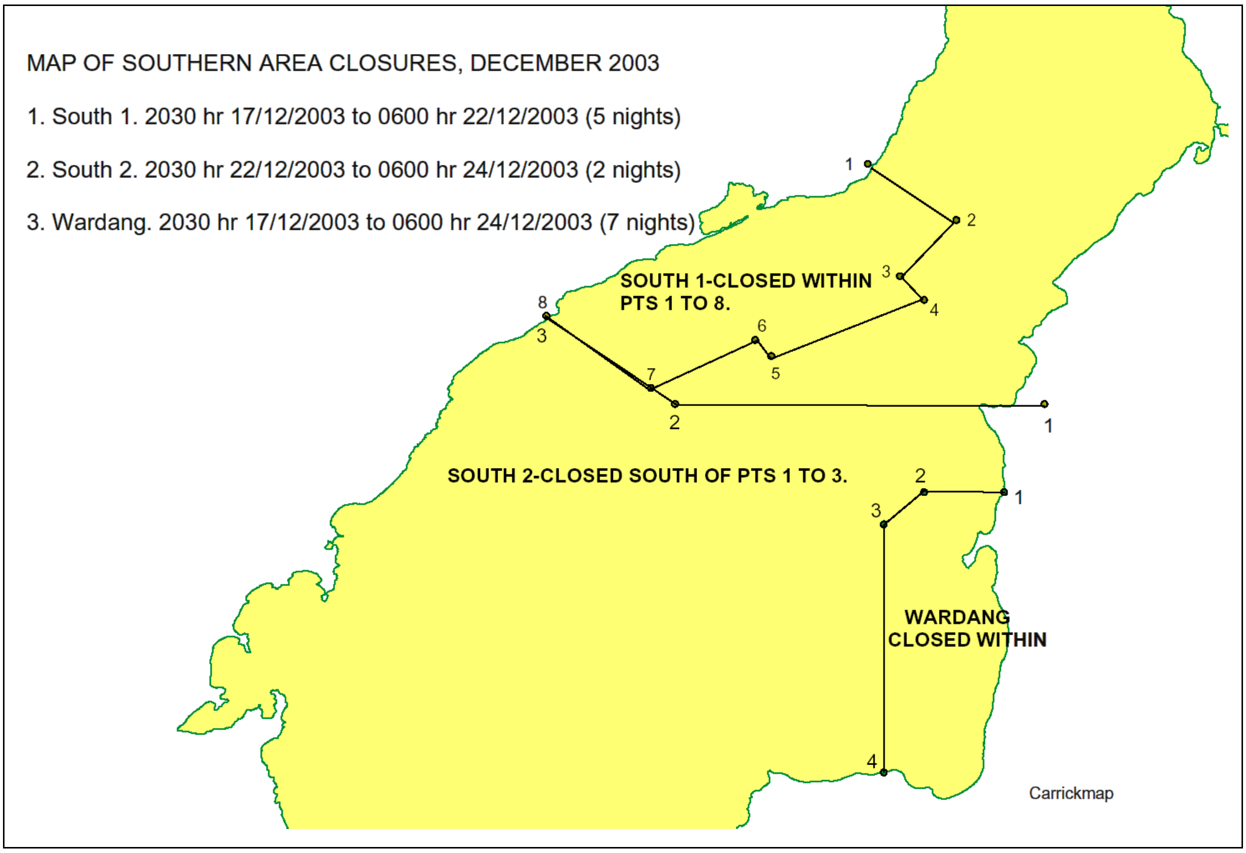
(iii) 2030 hr 17/12/2003 to 0600 hr 24/12/2003 (7 nights)-Wardang

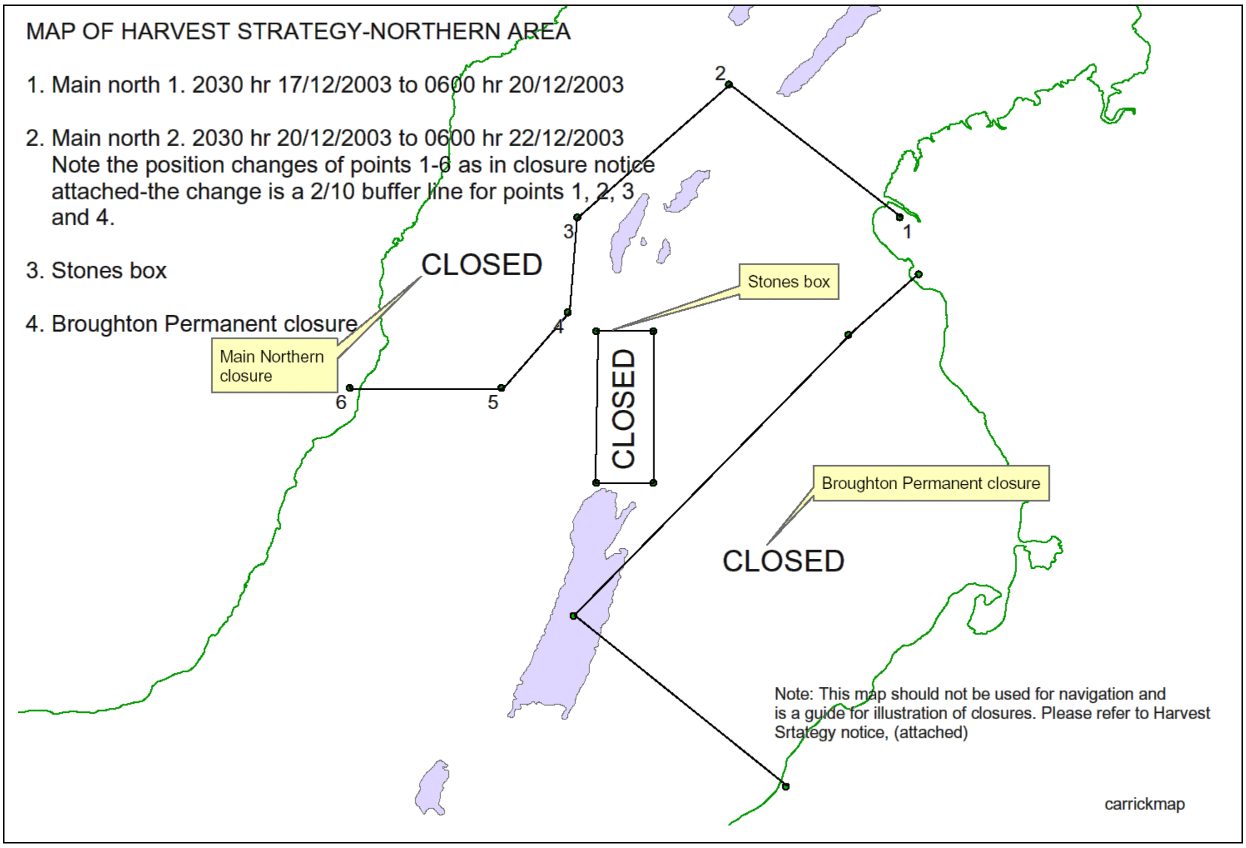
Trawling is prohibited within the following closure index points:

1. 34° 19.0’ S, 137° 30.0’E
2. 34° 19.0’ S, 137° 20.0’E
3. 34° 23.0’ S, 137° 15.0’E
4. 34° 54.0’ S, 137° 15.0’E

Neil Carrick
Senior Research Scientist
Spencer Gulf Prawn Fishery
Delegate of the Minister for Agriculture, Food & Fisheries
12/12/2003
0600 hr

Appendix 3c: Maps of closures available to the fishermen via internet

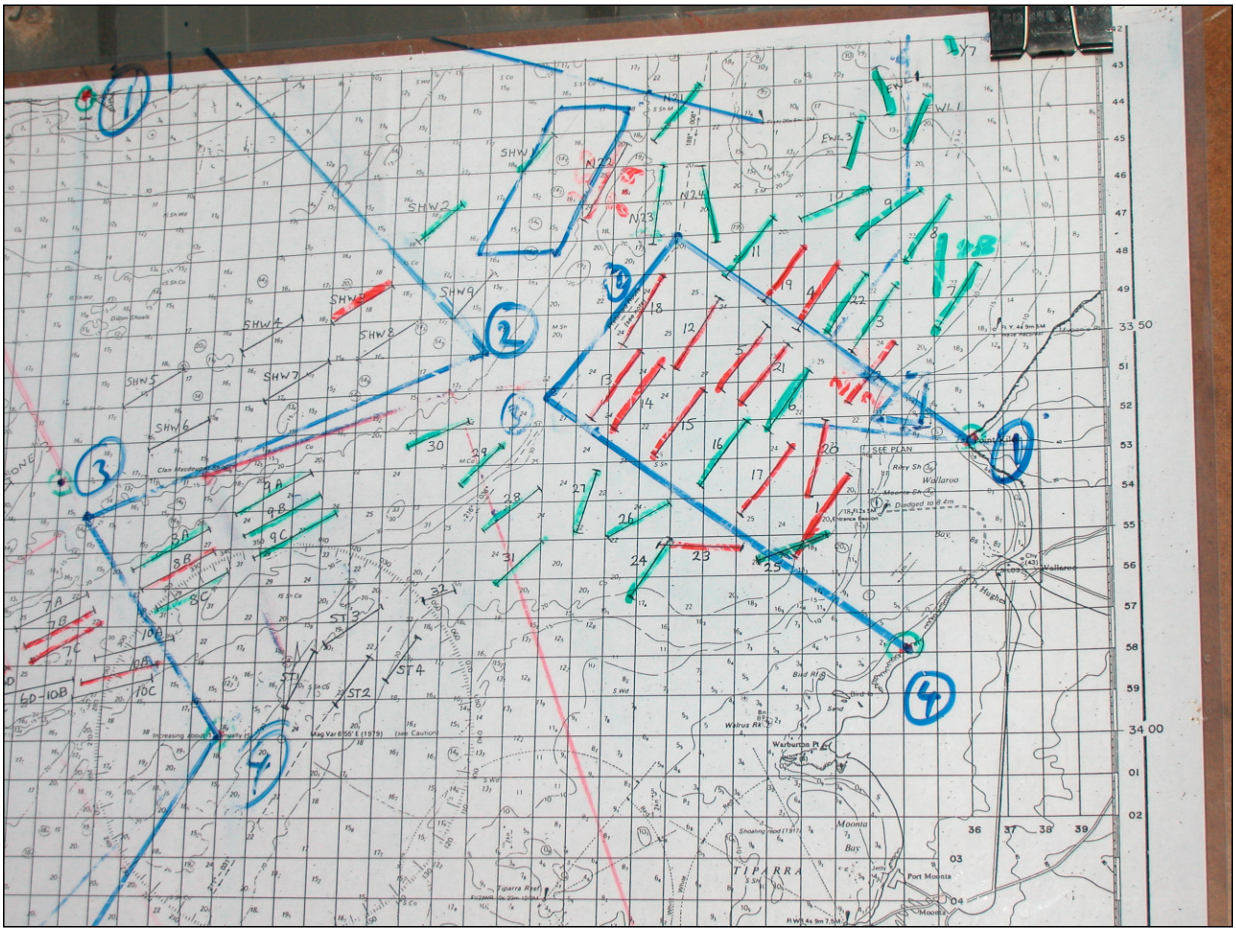




Appendix 4: Images-prawn survey sampling and harvest strategy meeting with industry.

Trained observers including the Hon. David Ridgway MLC measuring prawn samples during a trawl survey.

Harvest strategy meeting at held Wallaroo following April 2004 survey.



Harvest strategy meeting showing map of closure lines with trawl shots where green are larger prawns and red are below target size prawns.

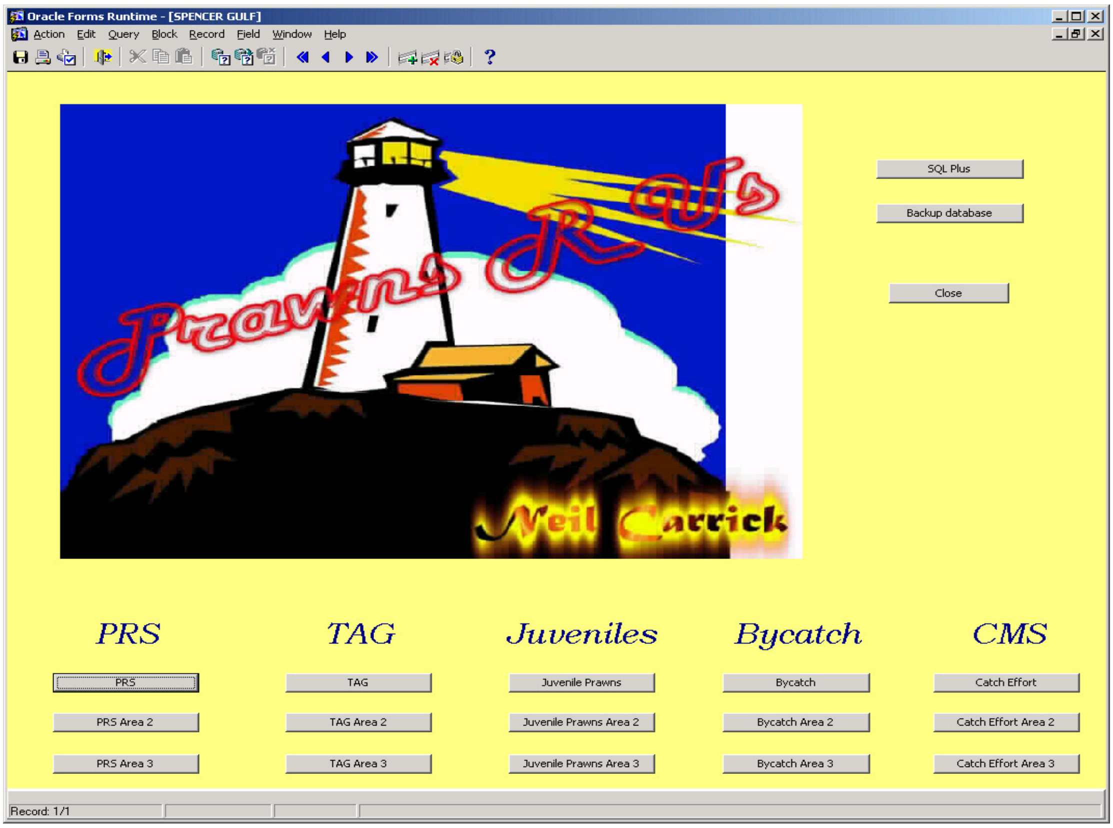
Appendix 5: Database documentation

Prawn Research System (PRS) database

Menu Structure

Main Menu (All applications)

Screen Title	Purpose	Form name & logon
PRS	PRS main menu SG	prs_main prs/prs
PRS Area 2	PRS main menu area 2	prs_main prs_sg/prs_sg
PRS Area 3	PRS main menu area 3	prs_main prs_wc/prs_wc
TAG	TAG main menu SG	tag_main tag/tag
TAG Area 2		tag_main tag_sg/tag_sg
TAG Area 3		tag_main tag/tag
Juvenile Prawns	JUV main menu SG	juv_main juv/juv
Juvenile Prawns Area 2		juv_main juv_sg /juv_sg
Juvenile Prawns Area 3		juv_main juv/juv
Bycatch	Bycatch main menu SG	byc_main byc/byc
Bycatch Area 2		byc_main byc_sg /byc_sg
Bycatch Area 3		byc_main byc/byc
CMS	Catch Monitoring System	ce_main ce/ce
CMS Area 2		ce_main ce_sg /ce_sg
CMS Area 3		ce_main ce/ce
SQL Plus	Ad hoc queries	You must logon
Backup Database	Master Backup screen	?



PRS Main Menu

Screen Title	Purpose	Form name
Surveys	Survey list	srv2
Log Data	Log data entry	log2

Sample data	Sample data entry	sam2
Reports	Run reports	rep2
Size and Catch	Grades	sct2
Grade Price Data	Price Grades	pri2
Vessels	List vessels	ves2
SURVEY VESSELS & POWER	List vessel power data	vep2
Stations	List all stations	stn2
Station Groups	List station groupings	shm2
Station Group Details	Detail of each station group	shd2
Station Master Model	Create station models (ie combine groups of stations into one model)	mam2
System Codes	System codes	cod2
Default Codes	Remember default values	dft2
Backup Database	Oracle export	
Close	Exit back to main menu	

Understanding the data

PRS data

Prawn surveys are conducted from prawn fishing boats at a range of geographic sites known as stations. See Station Data section for details.

Samples are taken from the main catch and recorded to provide a picture over time of prawn populations at stations.

Samples are recorded by prawn size, number and sex along with details such as temperature, catch depth, trawl time and distance.

PRS Data Tables

PRSDBSRV	Survey details.
PRSDBCOD	Codes used in PRS eg Area 01 = Spencers Gulf
PRSDBDFT	Used to remember default settings between sessions eg current survey
PRSDBLOG	Hold log data. One record for each survey for each vessel for each station.
PRSDBMAD	Used to store named sub groups of stations. Parent records are held in PRSDBMAM.
PRSDBMAM	Stations can be grouped for reporting purposes. Then these groups (sub groups in this case) can in turn be grouped into a "master" group for reporting purposes. These highest level groups are stored in this table. Detail records are held in
PRSDBPRI	Grade price data.
PRSDBSAM	Sample records. When a log record is created then initial sample records are created. A record for every size from 15 to 70 mm for Males and Females is created, and set to zero. At data entry time, these zeroes are replaced by the sample count where it is non zero.
PRSDBSAT	A table required "between" the log and sample tables to deal with both the possibility of occasional multiple samples (per logged station) and also the need to store summary data (total weights) per sample.
PRSDBSCT	Maps prawn size to grade.
PRSDBSHD	Details of which stations belong in the reporting groups stored in PRSDBSHM.
PRSDBSHM	A named group designed to group a number of stations for reporting purposes. Details records are held in PRSDBSHD.
PRSDBSTN	Stations details, including region, fishing block, start, end and mid GPS bearings.
PRSDBVEM	Designed to hold power indices for a vessel when more than 3 are defined for a vessel in any one survey.
PRSDBVEP	Holds the vessels defined as participating in a specific survey and up to 3 power indices for that period. Further indices can be stored in PRSDBVEM.
PRSDBVES	A master list of all vessels ever involved in surveys or likely to be in the future.

PRS Reporting Tables and Views

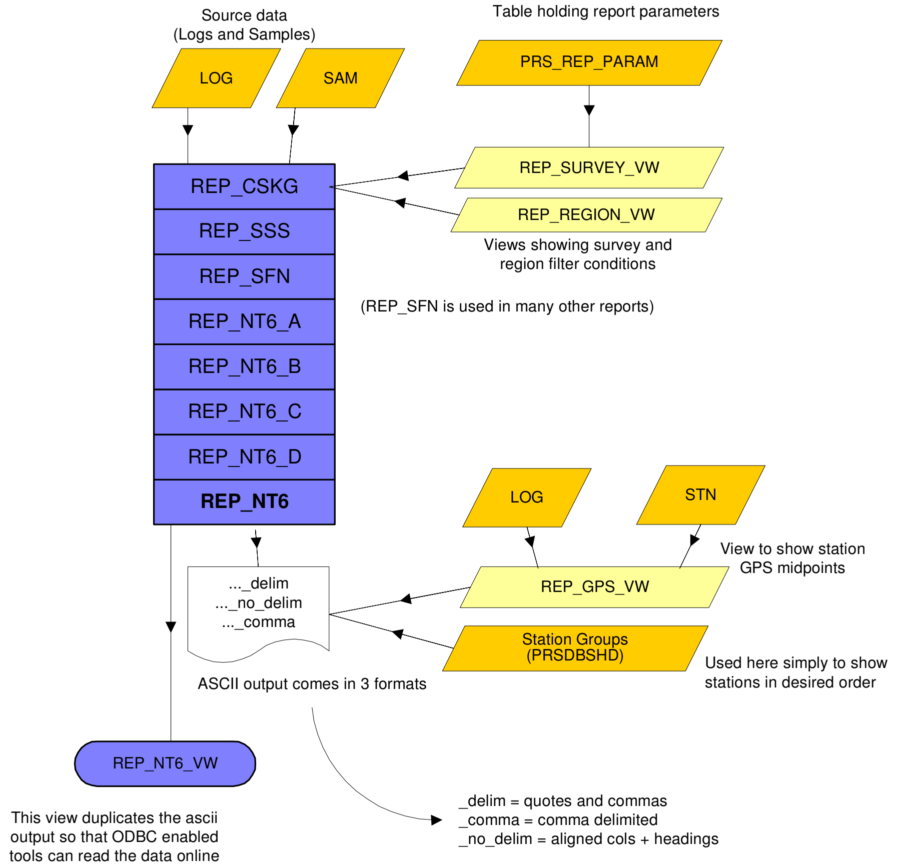
A SQL*Plus routine called REP_NT6 does much of the work to set up data for subsequent reporting. It takes several parameters such as survey, region and various sizes and clears out then creates fresh data in several key tables.

See source code for up to date details (rep_nt6.sql).

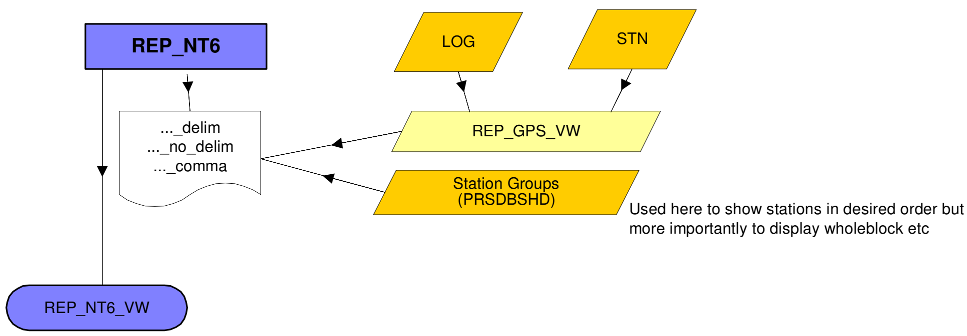
REP_NT6	populates these tables in the following order.
REP_CSKG	Populates survey, area, region, station, cskg.from PRSDBSAM.
REP_SSS	Populates survey, area, region, station, total_kg, skg, sample_wt_kg, logdate from PRSDBLOG and REP_CSKG.
REP_SFN	Populates survey, area, region, station, samsize, sex, no, ctno, total_kg, skg, ctkg, comgrade from PRSDBSCT, PRSDBSAM, REP_SSS.
REP_NT6_A	Male recruits < 33mm per Nautical Mile. Size limit here can be set in the main report screen.
REP_NT6_B	Female recruits < 35mm per Nautical Mile. Size limit here can be set in the main report screen.
REP_NT6_C	Total recruits per Nautical Mile.
REP_NT6_D	Female reproductive capacity (< 29mm). Size limit here can be set in the main report screen.
REP_NT6	Populates survey, area, region, station, mrecnm, frecnm, recrnm, tot_recnm, pct_recnm, rc, logdate from the previous 4 tables and REP_CSKG.
REP_GPS_VW	Is a view used to display GPS coordinates in a standard way. It takes the start and end points for a logged station from the log record. It displays the midpoint coordinates from the log record if it can calculate them from the log start and end points otherwise it shows the midpoint recorded in the station file. If neither can be shown then a blank midpoint is displayed.
REP_FAM	Holds data showing the calculated total no of prawns per kilometer below a specifid length. See rep_fam.sql.
REP_NT7A	Holds data showing totals and weights per nautical mile. See rep_nt7.sql

Report Diagrams

REPORTING ANATOMY
REP_NT6



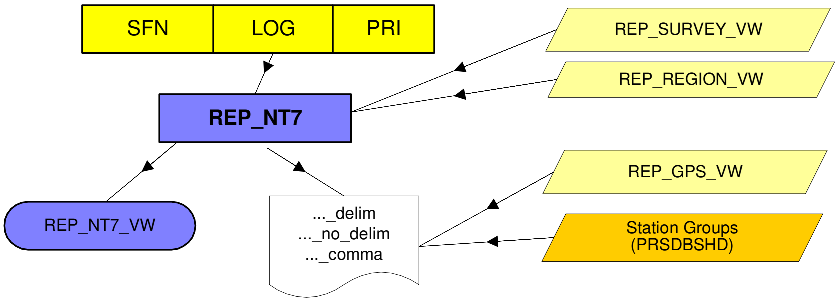
REP_NT6_OUT_with_Station_Model **(As above but includes Wholeblock etc from a specific Station Model)**



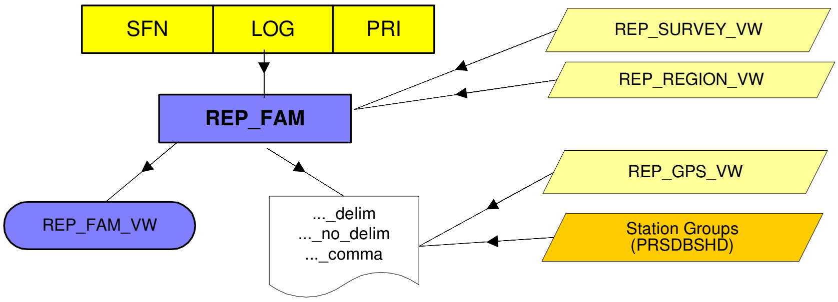
REPORTING ANATOMY

See REP_NT6
for more detail

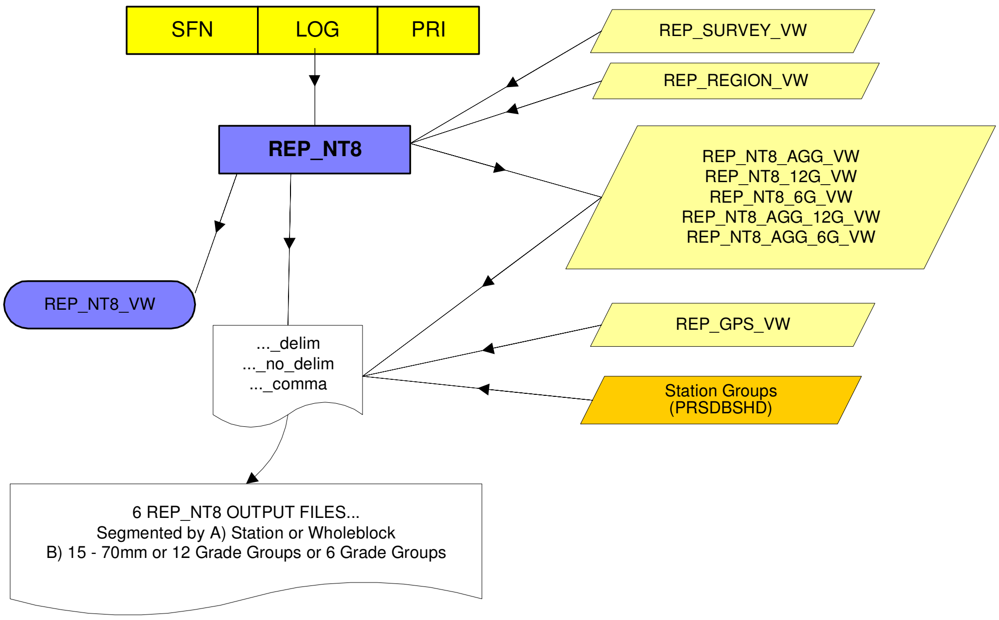
REP_NT7



REP_FAM

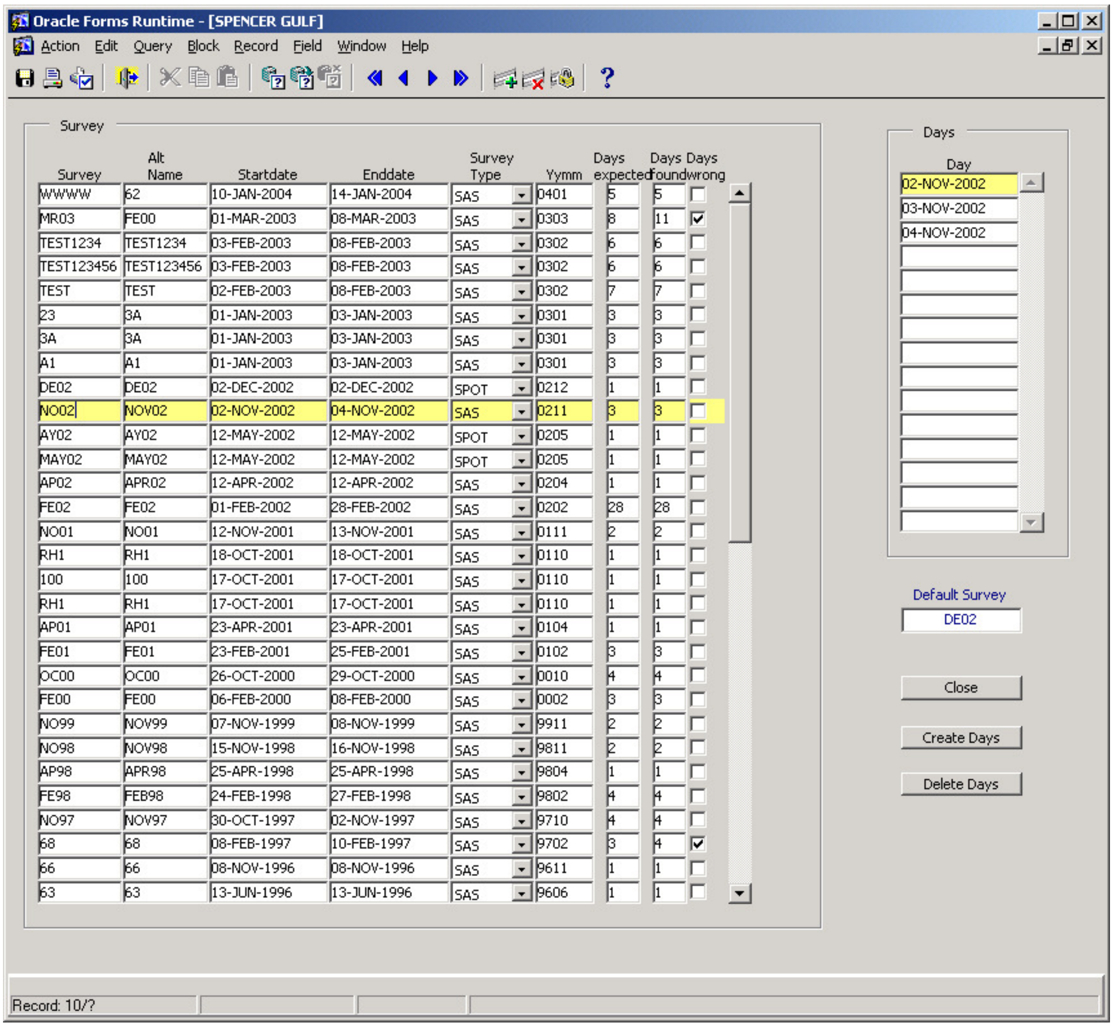


REP_NT8



PRS Forms

Surveys



Form name: SRV2.frm
Base table: PRSDBSRV
Unique key: Survey

FIELDS

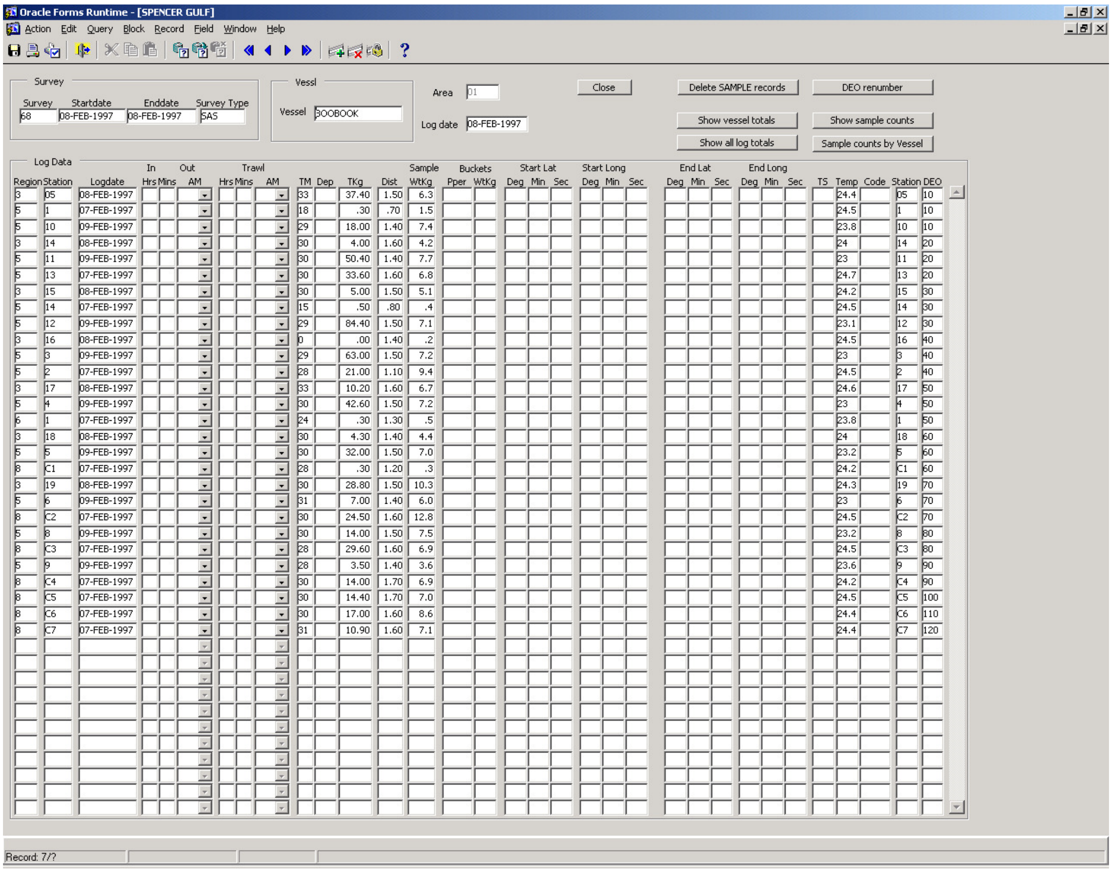
Screen name	Real name	Base Table	Note
Survey	SURVEY	✓	Unique survey name (identifier)
Alt name	ALT_NAME	✓	Shows original old survey name
Start date	STARTDATE	✓	
End date	ENDDATE	✓	
Survey Type	SURVEY_TYPE	✓	SAS or SPOT
Yymm	YYMM	✓	
Default Survey	CODE_VALUE	PRSDBDFT	LOV displays automatically

A survey is uniquely defined by its name (survey). The Alt (alternative) name is provided as an optional way of tracking the original name of the survey. It is intended that all older surveys will be renamed in accordance with the names used more recently. In this case the Alt name would allow matching back to the older original name.

The Days for each survey are used in the LOG screen and define the actual working days that comprise each survey. They are created automatically when a survey is created and saved in this survey screen. The 3 columns, Days Expected, Days Found and Days Wrong are used to highlight any inconsistency that might arise between the days calculated from the difference between the Survey Start and End dates. These can then be manually corrected.

The Default Survey is intended to make things easier in other screens by having PRS “remember” the survey being worked on. Change it by clicking in the Default Survey field.

Log Data



Form name: LOG2
Base table: PRSDBLOG
Unique key: Survey, Area, Region, Station
FIELDS

Screen name	Real name	Base Table	Note
Survey etc		PRSDBSRV	
Vessel		PRSDBVEP	Vessels must have

			been created for the survey from the vessel master list
Log date	Day	PRSDBDAY	Managed in Survey screen
Region	Region	PRSDBLOG	
Station	Station	"	
Logdate	Logdate	"	
In Hrs	Timein_hrs	"	
In Mins	Timein_mins	"	
In AM	Timein_ampm	"	
Out Hrs	Timeout_hrs	"	
Out Mins	Timeout_mins	"	
Out AM	Timeout_ampm	"	
TM	Trawl_mins	"	Time Mins
Dep	Trawl_depth	"	Depth
TKg	Total_kg	"	Total Kg
Dist	Trawl_distance	"	Distance Km
Sample WtKg	Sample_Wt_Kg	"	Sample Weight Kg
Buckets Pper	Prawns_per_bucket	"	
Buckets WtKg	Bucket_wt_kg	"	Buckets Weight Kg
Start Lat Deg	Start_lat_deg	"	
Start Lat Min		"	
Start Lat Sec	Start_lat_sec_alpha	"	
Start Long Deg		"	
Start Long Min		"	
Start Long Sec	Start_long_sec_alpha	"	
End Lat Deg		"	
End Lat Min		"	
End Lat Sec	End_lat_sec_alpha	"	
End Long Deg		"	
End Long Min		"	
End Long Sec	End_long_sec_alpha	"	
TS	Trawl_speed	"	Trawl Speed
Temp	Temp	"	Temperature
Code	Tide_code	"	Tide Code
Station	Station	"	
DEO	Data_entry_order	"	

Records the log data supplied by each vessel conducting the survey. Shows data such as station, GPS bearings, depth, temperature, time, trawl distance, sample and total catch weight.

For each log record there is a set of sample data, showing size frequency data for measured carapace length.

Note that first a survey must be created and the vessels for that survey nominated. It is assumed that all necessary stations are also already on record. All survey days must have been created in the survey screen.

Data validation occurs when each log record is saved with the display of advisory messages for each data element that violates the range rules. Such violations do not stop the data being saved. There is an SQL routine to subsequently check and report on any remaining violations for a nominated survey. Data can be edited in the screen at any later time. Note that some screens allow data to be locked to prevent unintentional changing of data although this has not yet been implemented in PRS.

Data is usually entered a day at a time but then when reviewed it may be helpful to see data for a vessel for all days on the one screen.The 3 buttons “Prev Day”, “Next Day” and “All Days” allow viewing or setting of the respective days as required.

A special menu can be displayed by clicking the right mouse button on the “Right click for menu” button (use the Right button to click this button). Right clicking with the mouse on most blank parts of the screen ie not buttons or fields will have the same effect.

The menu allows display of summary log and sample data and also provides a 2 specialist routines to ensure data integrity when special problems were encountered.
It also provides an option to control how Oracle form errors or messages are displayed. By default any of these are displayed prominently in a popup window. If preferred they can be made to appear instead less obtrusively at the bottom left of the screen.

The 2 specialist routines are:

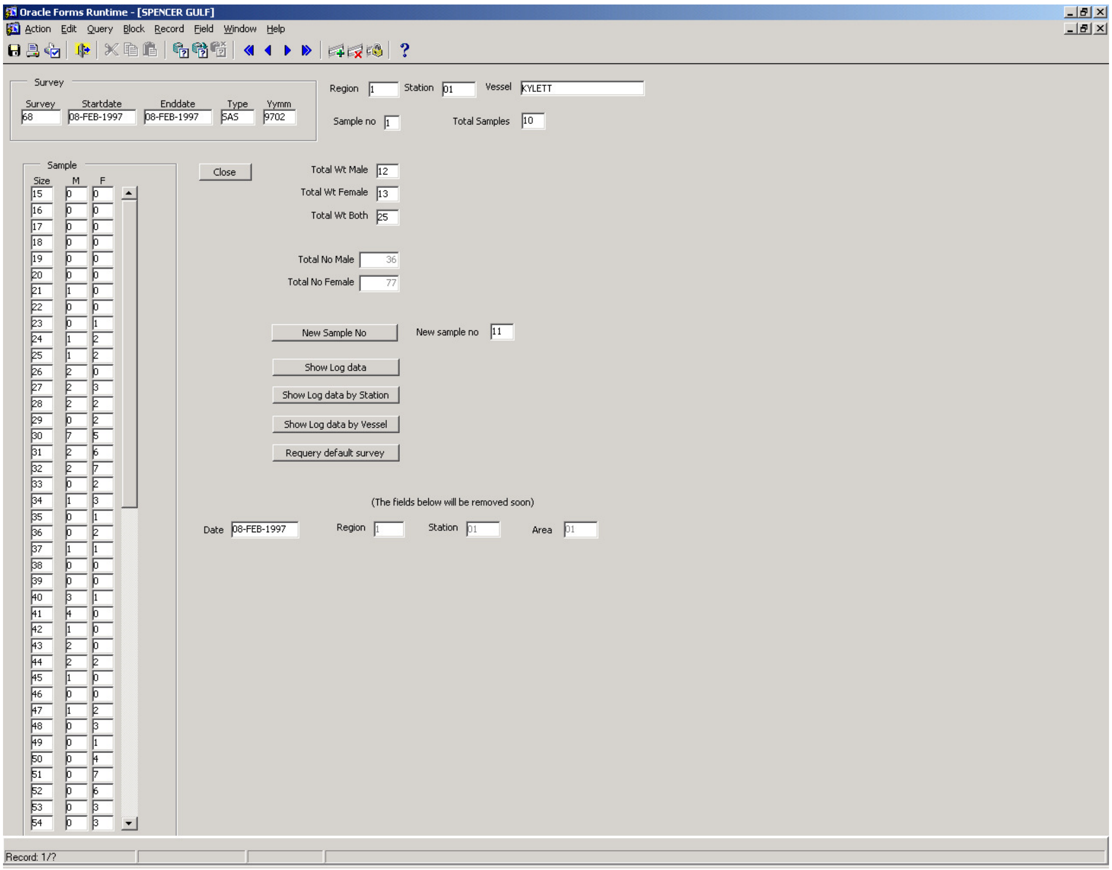
1. “Fix Samples” creates a set of sample records when none exist. This should not happen as they are normally created automatically when a log record is saved. Note that there is an automatic check which will advise you if for some reason this has not happened. If a warning message to this effect is displayed then this menu option can be run at any time to create the missing data (ie sample records for males and females 15 – 70mm set to zero size).

2. “Ensure all GPS seconds synchronized” is the other option which should never need to be used. Lat And Long Sec values displayed are held as alphanumeric values but also stored separately as numeric values. This was done to provide more user friendly treatment of these values at data entry. The form automatically synchronises these non numeric and numeric pairs of values. It is not expected that this would ever not occur but as an added precaution an extra check is done to monitor this. If any values are not synchronized then this menu option can be run at any time to correct this. It will probably never be needed.

Use DEO to preserve the physical order of entry. Manually edit these numbers if required.

Use the “Limit Vessel Shown” when reviewing log data after it has been entered to avoid having to toggle through vessels that have no log records.

Sample data



Form name: SAM3
Base table: PRSDBSAM
Unique key: Survey, Area, Region, Station, Sub_sample_no, samsize

FIELDS

Screen name	Real name	Base Table	Note
Survey etc		PRSDBSRV	
Date	-	Derived	
Region		PRSDBLOG	
Station		PRSDBLOG	
Vessel		PRSDBLOG	
Total Wt Both	TOTAL_WT_BOTH	PRSDBSAT	
Total Wt Male	TOTAL_WT_MALE	PRSDBSAT	
Total Wt Female	TOTAL_WT_FEMALE	PRSDBSAT	
Sample No		PRSDBSAT	
Total No Male	-	Derived	
Total No Female	-	Derived	
Size	SAMSIZE	PRSDBSAM	15 – 70mm
M	MALES	PRSDBSAM	
F	FEMALES	PRSDBSAM	

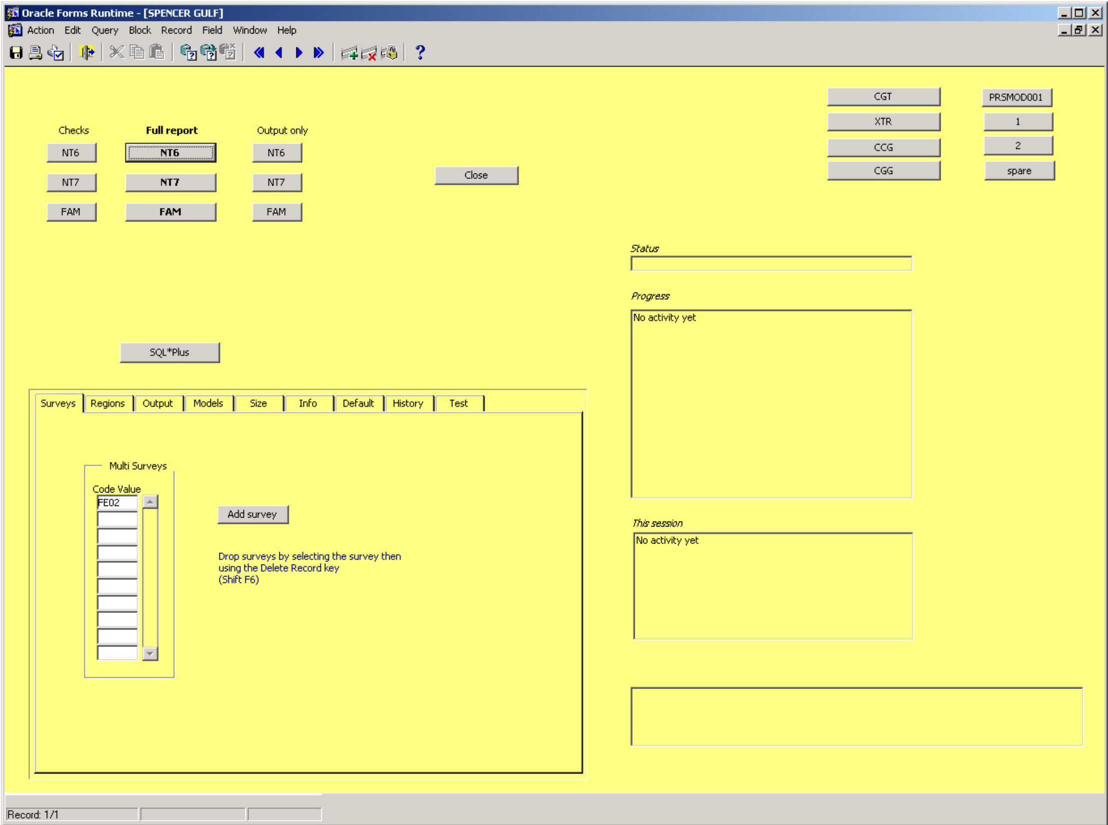
The size frequency data from each station survey sample. Length (size) is measured and displayed by sex and size (15 - 70mm).

A log record must be created first.

Multiple sub samples may be entered in those rarer cases where there are more than one sample per station.

The system creates a record for each sex and size when the log record is first created, setting measured size to zero for each length 15 – 70 mm, at this point.

Reports



Form name: REP2
Base table: N/App
Unique key: N/App

Allows running of some main reports and setting of parameters used by these reports. This includes setting of specific survey(s) to reported on, regions to be included and/or excluded as well as some size parameters.

Reports run in a separate Oracle product called SQL*Plus to allow ad hoc reporting outside the structured screen framework.

Output destinations can be set in this screen.

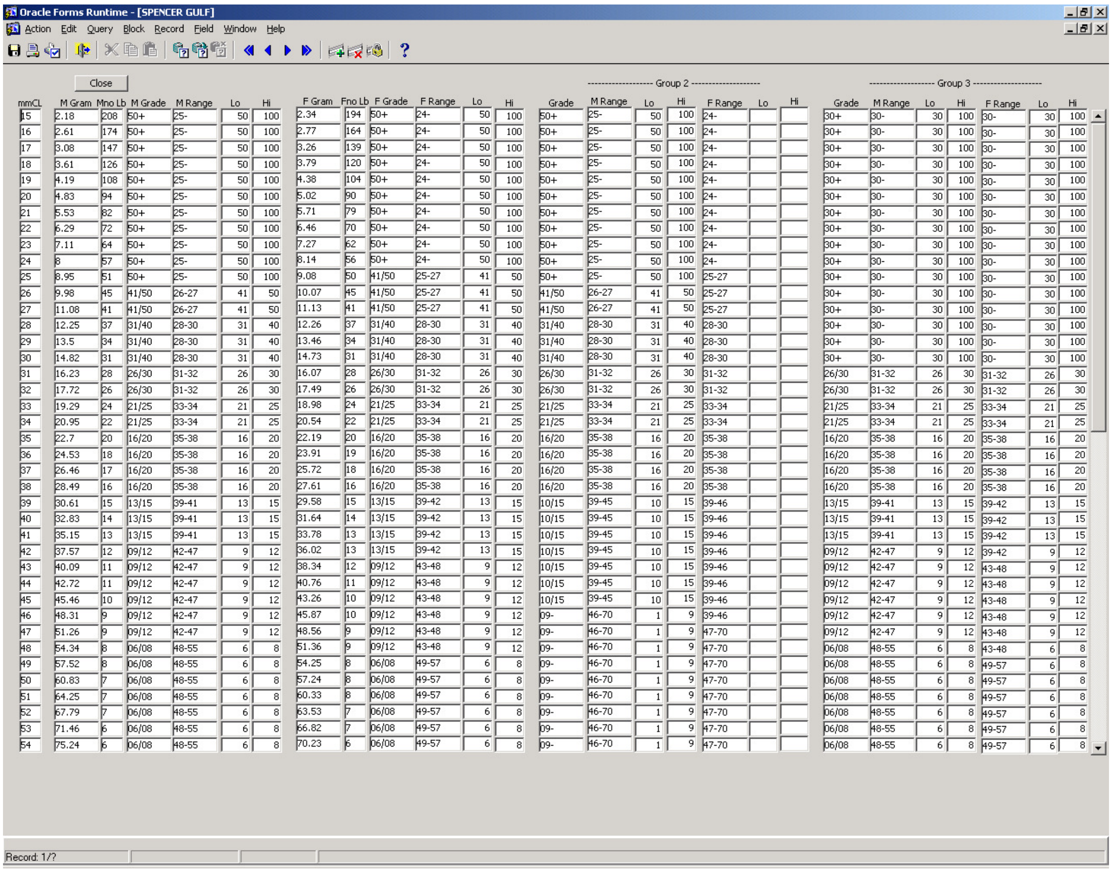
Report parameters that can be set in this screen include:

Survey(s)
Region(s) included and excluded
Output file locations
Output file names

Location of sql files that are run as reports

Size parameters for selected reports
Station models for selected reports

Size and Catch



Oracle Forms Runtime - [SPENCER GULF]

Action Edit Query Block Record Field Window Help

Close

mmCL	M Gram	Mno Lb	M Grade	M Range	Lo	Hi	F Gram	Fno Lb	F Grade	F Range	Lo	Hi
15	2.18	208	50+	25-	50	100	2.34	194	50+	24-	50	100
16	2.61	174	50+	25-	50	100	2.77	164	50+	24-	50	100
17	3.08	147	50+	25-	50	100	3.26	139	50+	24-	50	100
18	3.61	126	50+	25-	50	100	3.79	120	50+	24-	50	100
19	4.19	108	50+	25-	50	100	4.38	104	50+	24-	50	100
20	4.83	94	50+	25-	50	100	5.02	90	50+	24-	50	100
21	5.53	82	50+	25-	50	100	5.71	79	50+	24-	50	100
22	6.29	72	50+	25-	50	100	6.46	70	50+	24-	50	100
23	7.11	64	50+	25-	50	100	7.27	62	50+	24-	50	100
24	8	57	50+	25-	50	100	8.14	56	50+	24-	50	100
25	8.95	51	50+	25-	50	100	9.08	50	41/50	25-27	41	50
26	9.98	45	41/50	26-27	41	50	10.07	45	41/50	25-27	41	50
27	11.08	41	41/50	26-27	41	50	11.13	41	41/50	25-27	41	50
28	12.25	37	31/40	28-30	31	40	12.26	37	31/40	28-30	31	40
29	13.5	34	31/40	28-30	31	40	13.46	34	31/40	28-30	31	40
30	14.82	31	31/40	28-30	31	40	14.73	31	31/40	28-30	31	40
31	16.23	28	26/30	31-32	26	30	16.07	28	26/30	31-32	26	30
32	17.72	26	26/30	31-32	26	30	17.49	26	26/30	31-32	26	30
33	19.29	24	21/25	33-34	21	25	18.98	24	21/25	33-34	21	25
34	20.95	22	21/25	33-34	21	25	20.54	22	21/25	33-34	21	25
35	22.7	20	16/20	35-38	16	20	22.19	20	16/20	35-38	16	20
36	24.53	18	16/20	35-38	16	20	23.91	19	16/20	35-38	16	20
37	26.46	17	16/20	35-38	16	20	25.72	18	16/20	35-38	16	20
38	28.49	16	16/20	35-38	16	20	27.61	16	16/20	35-38	16	20
39	30.61	15	13/15	39-41	13	15	29.58	15	13/15	39-42	13	15
40	32.83	14	13/15	39-41	13	15	31.64	14	13/15	39-42	13	15
41	35.15	13	13/15	39-41	13	15	33.78	13	13/15	39-42	13	15
42	37.57	12	09/12	42-47	9	12	36.02	13	13/15	39-42	13	15
43	40.09	11	09/12	42-47	9	12	38.34	12	09/12	43-48	9	12
44	42.72	11	09/12	42-47	9	12	40.76	11	09/12	43-48	9	12
45	45.46	10	09/12	42-47	9	12	43.26	10	09/12	43-48	9	12
46	48.31	9	09/12	42-47	9	12	45.87	10	09/12	43-48	9	12
47	51.26	9	09/12	42-47	9	12	48.56	9	09/12	43-48	9	12
48	54.34	8	06/08	48-55	6	8	51.36	9	09/12	43-48	9	12
49	57.52	8	06/08	48-55	6	8	54.25	8	06/08	49-57	6	8
50	60.83	7	06/08	48-55	6	8	57.24	8	06/08	49-57	6	8
51	64.25	7	06/08	48-55	6	8	60.33	8	06/08	49-57	6	8
52	67.79	7	06/08	48-55	6	8	63.53	7	06/08	49-57	6	8
53	71.46	6	06/08	48-55	6	8	66.82	7	06/08	49-57	6	8
54	75.24	6	06/08	48-55	6	8	70.23	6	06/08	49-57	6	8

mmCL	------------------ Group 2 ------------------							------------------ Group 3 ------------------						
	Grade	M Range	Lo	Hi	F Range	Lo	Hi	Grade	M Range	Lo	Hi	F Range	Lo	Hi
15	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
16	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
17	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
18	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
19	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
20	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
21	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
22	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
23	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
24	50+	25-	50	100	24-			30+	30-	30	100	30-	30	100
25	50+	25-	50	100	25-27			30+	30-	30	100	30-	30	100
26	41/50	26-27	41	50	25-27			30+	30-	30	100	30-	30	100
27	41/50	26-27	41	50	25-27			30+	30-	30	100	30-	30	100
28	31/40	28-30	31	40	28-30			30+	30-	30	100	30-	30	100
29	31/40	28-30	31	40	28-30			30+	30-	30	100	30-	30	100
30	31/40	28-30	31	40	28-30			30+	30-	30	100	30-	30	100
31	26/30	31-32	26	30	31-32			26/30	31-32	26	30	31-32	26	30
32	26/30	31-32	26	30	31-32			26/30	31-32	26	30	31-32	26	30
33	21/25	33-34	21	25	33-34			21/25	33-34	21	25	33-34	21	25
34	21/25	33-34	21	25	33-34			21/25	33-34	21	25	33-34	21	25
35	16/20	35-38	16	20	35-38			16/20	35-38	16	20	35-38	16	20
36	16/20	35-38	16	20	35-38			16/20	35-38	16	20	35-38	16	20
37	16/20	35-38	16	20	35-38			16/20	35-38	16	20	35-38	16	20
38	16/20	35-38	16	20	35-38			16/20	35-38	16	20	35-38	16	20
39	10/15	39-45	10	15	39-46			13/15	39-41	13	15	39-42	13	15
40	10/15	39-45	10	15	39-46			13/15	39-41	13	15	39-42	13	15
41	10/15	39-45	10	15	39-46			13/15	39-41	13	15	39-42	13	15
42	10/15	39-45	10	15	39-46			09/12	42-47	9	12	39-42	9	12
43	10/15	39-45	10	15	39-46			09/12	42-47	9	12	43-48	9	12
44	10/15	39-45	10	15	39-46			09/12	42-47	9	12	43-48	9	12
45	10/15	39-45	10	15	39-46			09/12	42-47	9	12	43-48	9	12
46	09-	46-70	1	9	39-46			09/12	42-47	9	12	43-48	9	12
47	09-	46-70	1	9	47-70			09/12	42-47	9	12	43-48	9	12
48	09-	46-70	1	9	47-70			06/08	48-55	6	8	43-48	6	8
49	09-	46-70	1	9	47-70			06/08	48-55	6	8	49-57	6	8
50	09-	46-70	1	9	47-70			06/08	48-55	6	8	49-57	6	8
51	09-	46-70	1	9	47-70			06/08	48-55	6	8	49-57	6	8
52	09-	46-70	1	9	47-70			06/08	48-55	6	8	49-57	6	8
53	09-	46-70	1	9	47-70			06/08	48-55	6	8	49-57	6	8
54	09-	46-70	1	9	47-70			06/08	48-55	6	8	49-57	6	8

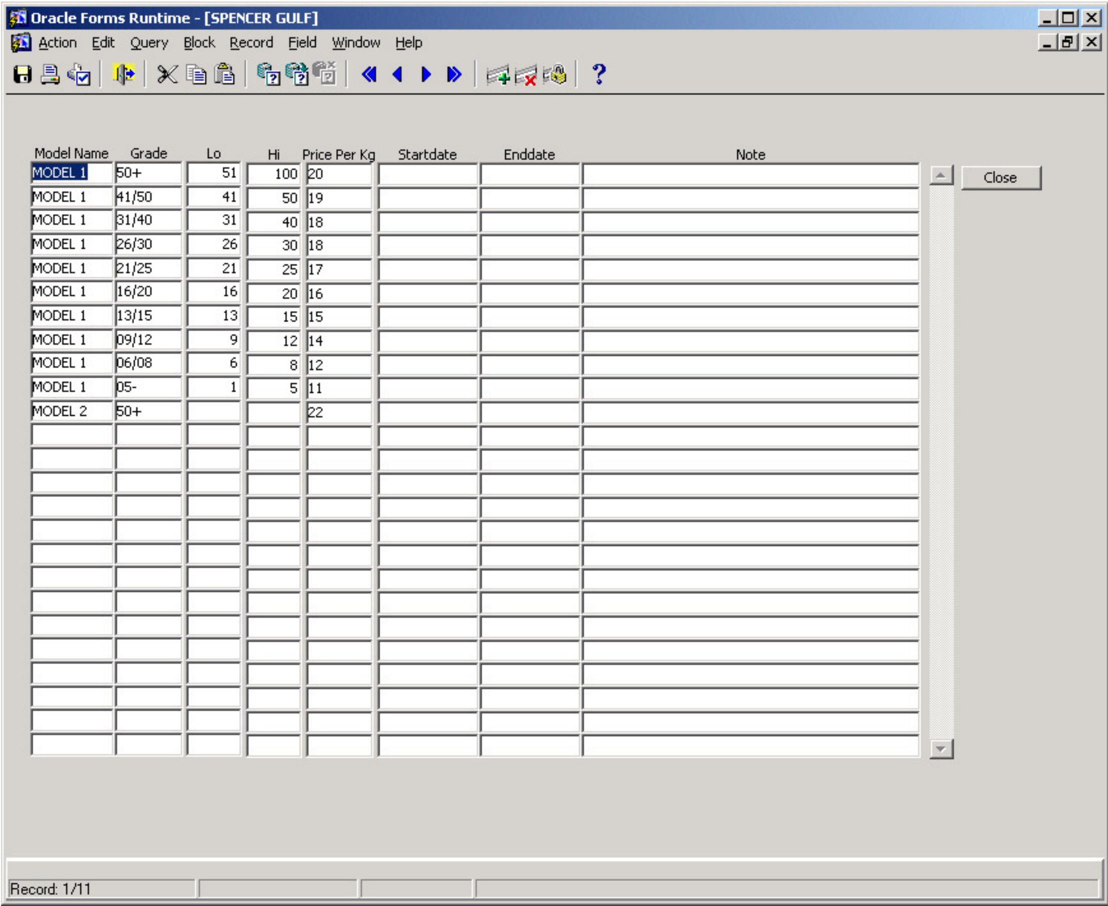
Record: 1/?

Form name: SCT2
Base table: PRSDBSCT
Unique key: SCTSIZE

Maps male and female sizes (carapace lengths) to the correct grade. Note that there are 3 different sets of grades that can be mapped to (see screen headings “Group2” and “Group3”.

This form is currently under review and may be superseded by a more comprehensive treatment of grades in PRS.

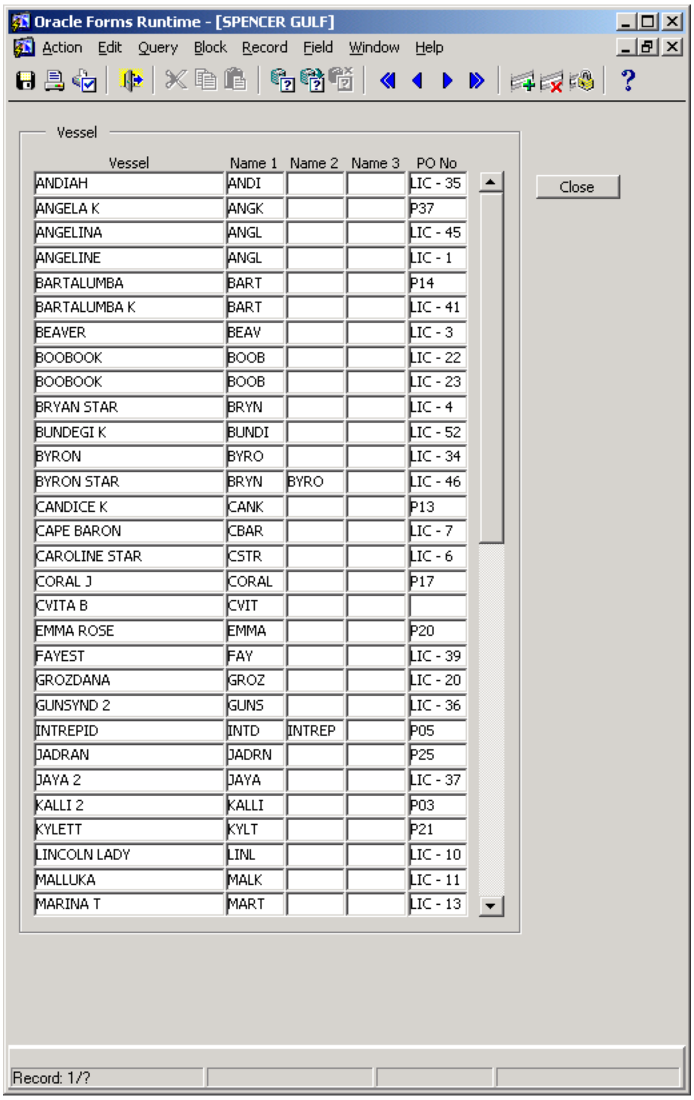
Grade Price Data



Model Name	Grade	Lo	Hi	Price Per Kg	Startdate	Enddate	Note
MODEL 1	50+	51	100	20			
MODEL 1	41/50	41	50	19			
MODEL 1	31/40	31	40	18			
MODEL 1	26/30	26	30	18			
MODEL 1	21/25	21	25	17			
MODEL 1	16/20	16	20	16			
MODEL 1	13/15	13	15	15			
MODEL 1	09/12	9	12	14			
MODEL 1	06/08	6	8	12			
MODEL 1	05-	1	5	11			
MODEL 2	50+			22			

Price per Kg per grade. Grades are grouped into Model1 and optionally other groups to allow for modelling of different prices. See also price data stored in CMS.

Vessels



Form name: VES2
Base table: PRSDBVES
Unique key: VESSEL

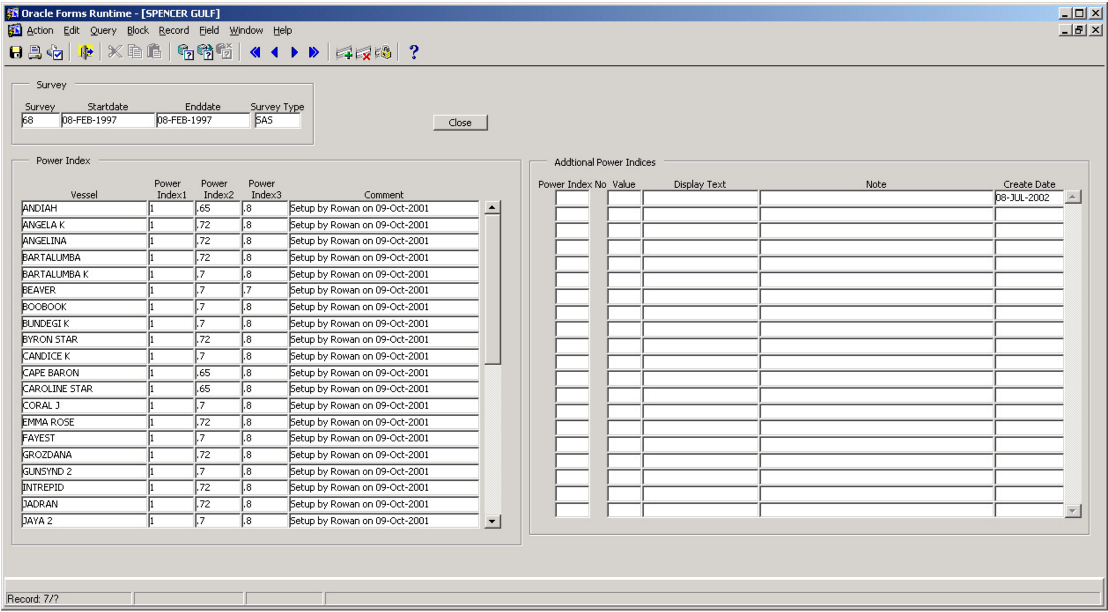
FIELDS

Screen name	Real name	Base Table	Note
Vessel	Vessel	PRSDBVES	
Name 1	Vessel_shortname1	"	
Name 2	Vessel_shortname2	"	
Name 3	Vessel_shortname3	"	
PO No	Vessel_licence_no	"	

A master list of all vessels used in any survey. Allows up to 3 optional short names (as used in the actual fleet over the years). Provides also for a PO number (see also vessel Licence numbers as recorded in CMS).

Note that vessels used in a specific survey must also have this use recorded in the Survey Vessels and Power screen.

Survey Vessels & Power



Form name: VEP2
Base table: PRSDBVEP
Unique key: Survey, vessel

FIELDS

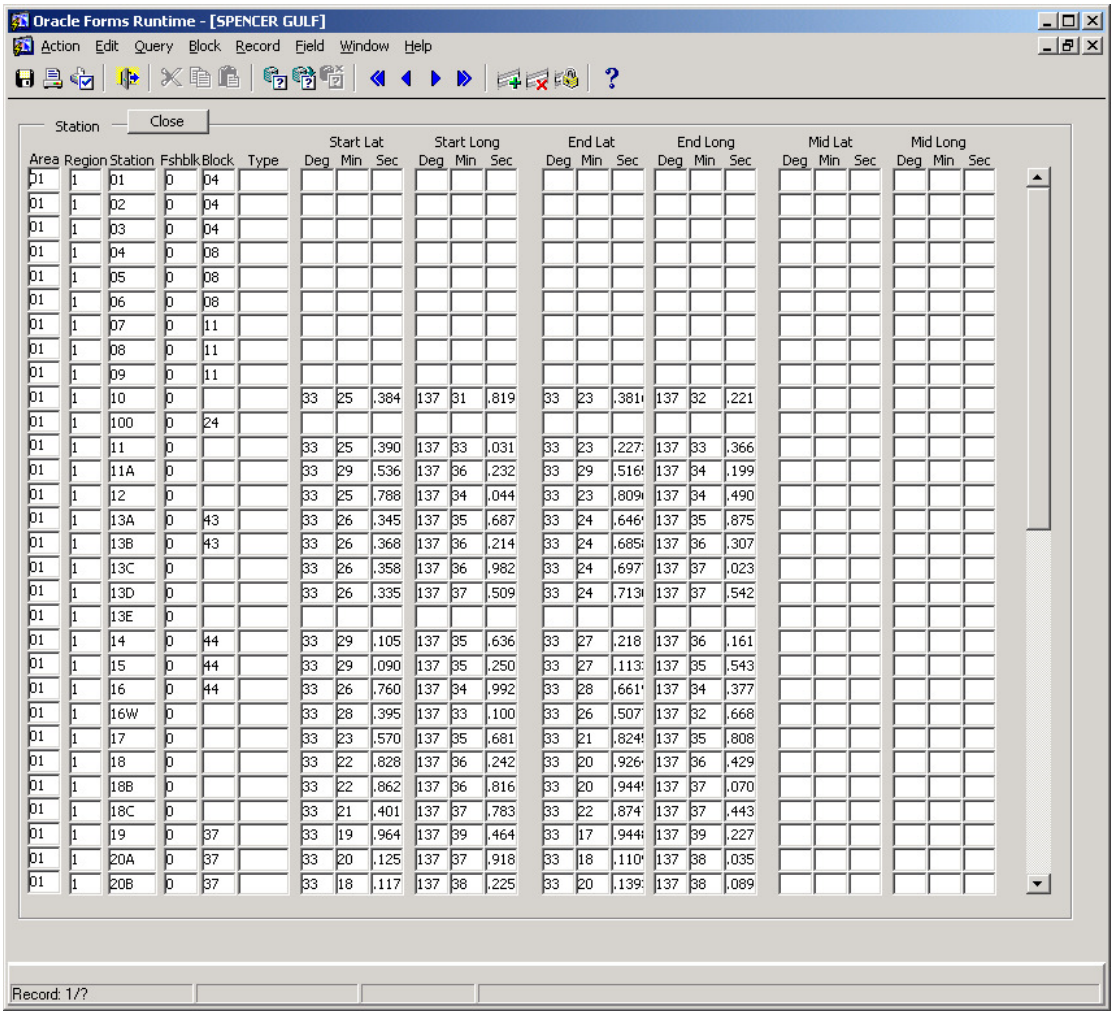
Screen name	Real name	Base Table	Note
Survey etc		PRSDBSRV	
Vessel		PRSDBVEP	
Power Index 1		"	
Power Index 1		"	
Power Index 1		"	
Comment	Note	"	
Power Index No	Power_Index_No	PRSDBVEM	Optional further index values > 3 indexes
Value	Power_index_value	"	
Display Text		"	
Note		"	
Create Date	Create_date	"	

Records which vessels were used in a survey. Also records their Power Index (3 "normal" indices plus optional further ones.

These are calculated manually. See also the Vessel Equipment Data screens in CMS which might have some bearing on how these indices are calculated.

The idea of a vessel power index is that a more powerful boat, or the same boat made more powerful over time, has to be weighted when comparing survey results from another less powerful boat (which other things being equal, might catch less under the same conditions).

Stations



Oracle Forms Runtime - [SPENCER GULF]

Action Edit Query Block Record Field Window Help

Station Close

Area	Region	Station	Fshblk	Block	Type	Start Lat Deg	Start Lat Min	Start Lat Sec	Start Long Deg	Start Long Min	Start Long Sec	End Lat Deg	End Lat Min	End Lat Sec	End Long Deg	End Long Min	End Long Sec	Mid Lat Deg	Mid Lat Min	Mid Lat Sec	Mid Long Deg	Mid Long Min	Mid Long Sec
01	1	01	0	04																			
01	1	02	0	04																			
01	1	03	0	04																			
01	1	04	0	08																			
01	1	05	0	08																			
01	1	06	0	08																			
01	1	07	0	11																			
01	1	08	0	11																			
01	1	09	0	11																			
01	1	10	0			33	25	.384	137	31	.819	33	23	.381	137	32	.221						
01	1	100	0	24																			
01	1	11	0			33	25	.390	137	33	.031	33	23	.227	137	33	.366						
01	1	11A	0			33	29	.536	137	36	.232	33	29	.516	137	34	.199						
01	1	12	0			33	25	.788	137	34	.044	33	23	.809	137	34	.490						
01	1	13A	0	43		33	26	.345	137	35	.687	33	24	.646	137	35	.875						
01	1	13B	0	43		33	26	.368	137	36	.214	33	24	.685	137	36	.307						
01	1	13C	0			33	26	.358	137	36	.982	33	24	.697	137	37	.023						
01	1	13D	0			33	26	.335	137	37	.509	33	24	.713	137	37	.542						
01	1	13E	0																				
01	1	14	0	44		33	29	.105	137	35	.636	33	27	.218	137	36	.161						
01	1	15	0	44		33	29	.090	137	35	.250	33	27	.113	137	35	.543						
01	1	16	0	44		33	26	.760	137	34	.992	33	28	.661	137	34	.377						
01	1	16W	0			33	28	.395	137	33	.100	33	26	.507	137	32	.668						
01	1	17	0			33	23	.570	137	35	.681	33	21	.824	137	35	.808						
01	1	18	0			33	22	.828	137	36	.242	33	20	.926	137	36	.429						
01	1	18B	0			33	22	.862	137	36	.816	33	20	.944	137	37	.070						
01	1	18C	0			33	21	.401	137	37	.783	33	22	.874	137	37	.443						
01	1	19	0	37		33	19	.964	137	39	.464	33	17	.944	137	39	.227						
01	1	20A	0	37		33	20	.125	137	37	.918	33	18	.110	137	38	.035						
01	1	20B	0	37		33	18	.117	137	38	.225	33	20	.139	137	38	.089						

Record: 1/?

Form name: STN2
Base table: PRSDBSTN
Unique key: Area, region, station

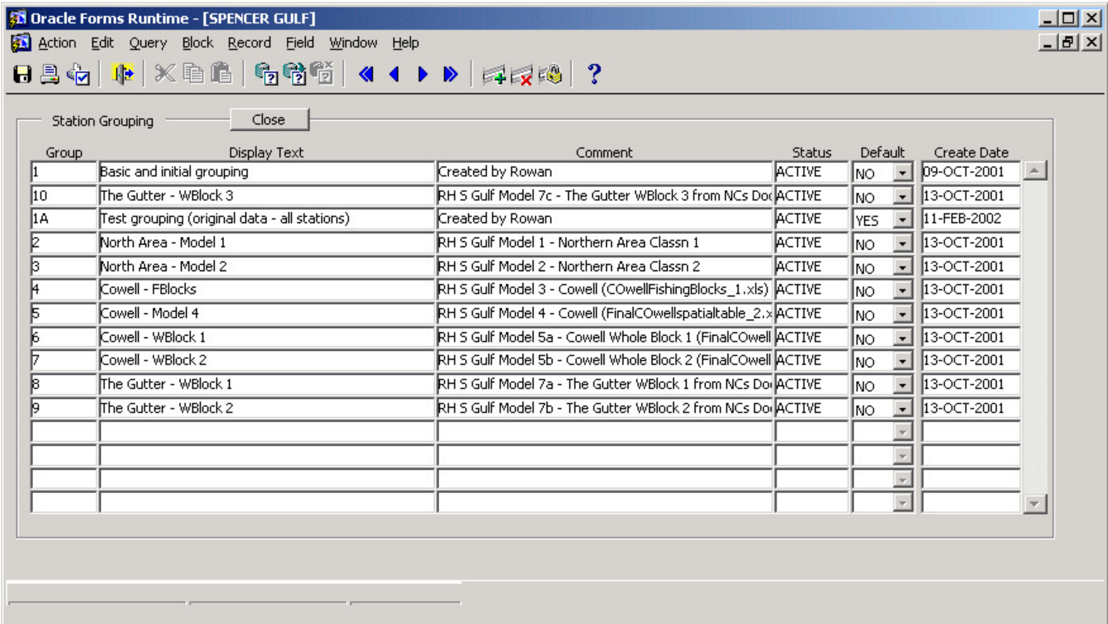
FIELDS

Screen name	Real name	Base Table	Note
Area		PRSDBSTN	
Region		"	
Station		"	
Fshblk		"	Fishing block
Block		"	Block
Type		"	Not used yet
Start Lat Deg	Start_lat_deg	"	
Start Lat Min		"	
Start Lat Sec	Start_lat_sec	"	
Start Long Deg		"	
Start Long Min		"	
Start Long Sec	Start_long_sec	"	
End Lat Deg		"	

End Lat Min		“	
End Lat Sec	End_lat_sec	“	
End Long Deg		“	
End Long Min		“	
End Long Sec	End_long_sec	“	
Mid Lat Deg		“	
Mid Lat Min		“	
Mid Lat Sec		“	
Mid Long Deg		“	
Mid Long Min		“	
Mid Long Sec		“	

The mastger list of Survey stations and their start, end and mid points (Latitude and Longitude).

Station Groups



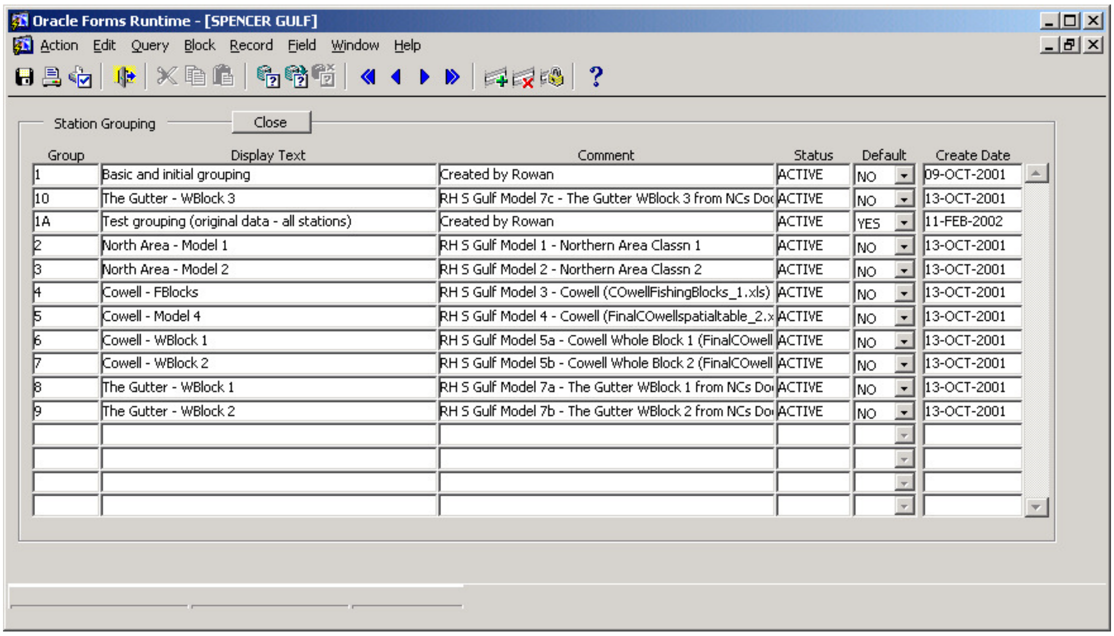
Form name: shm2
Base table: PRSDBSHM (Station Hierarchy Master)
Unique key: STN_GROUP

FIELDS

Screen name	**Real name**	**Base Table**	**Note**
Group	STN_GROUP	PRSDBSHM	
Display Text	STN_GROUP_DISPLAY_TEXT	“	
Comment	STN_GROUP_DISPLAY_COMMENT	“	
Status	STN_GROUP_STATUS	“	
Default	STN_GROUP_DEFAULT	“	
Create Date	CREATE_DATE	“	

Allows creation of a named group of stations. Used in later reporting on selected groups of stations.

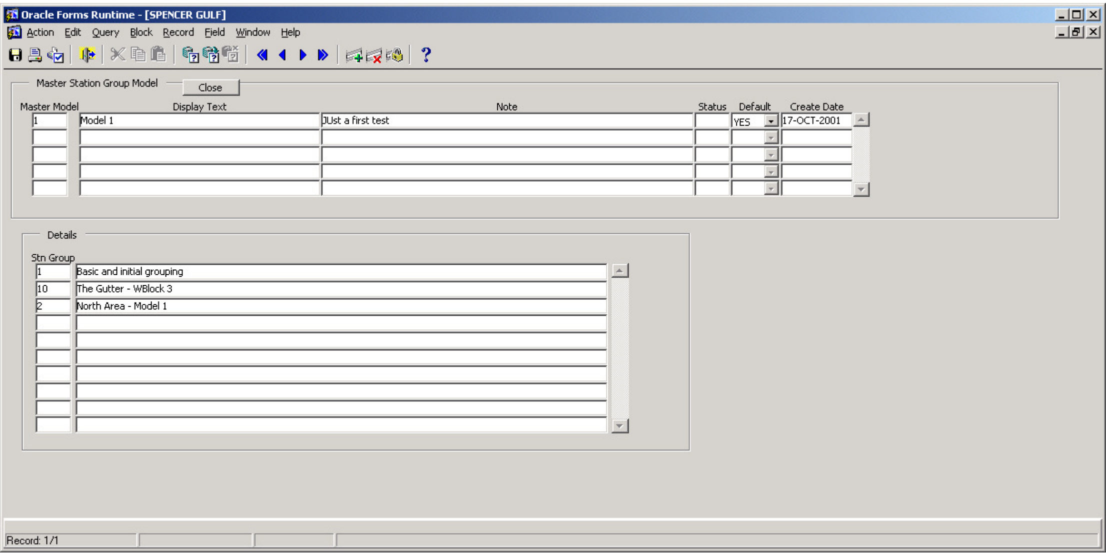
Station Group Details



Lists the stations in a named group of stations. Used in later reporting on selected groups of stations.

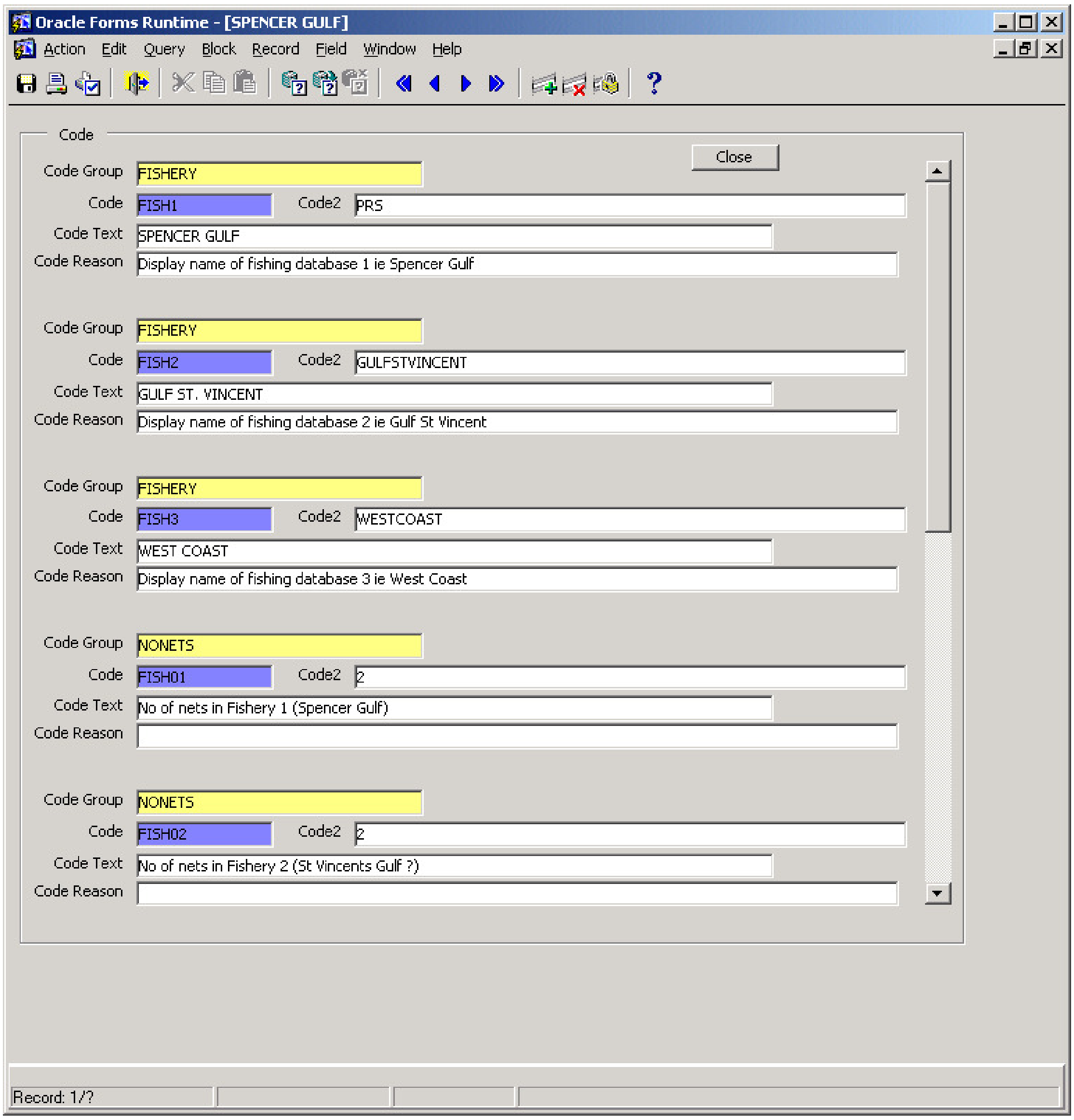
Allows ordering of stations within these groups for reporting purposes, though fields like Stn Order, Ordgrp, Stntype, Field1, Field2, Field3.

Station Master Model



Allows combination of Station Groups into a higher level group. Used in later reporting on selected groups of stations.

System Codes

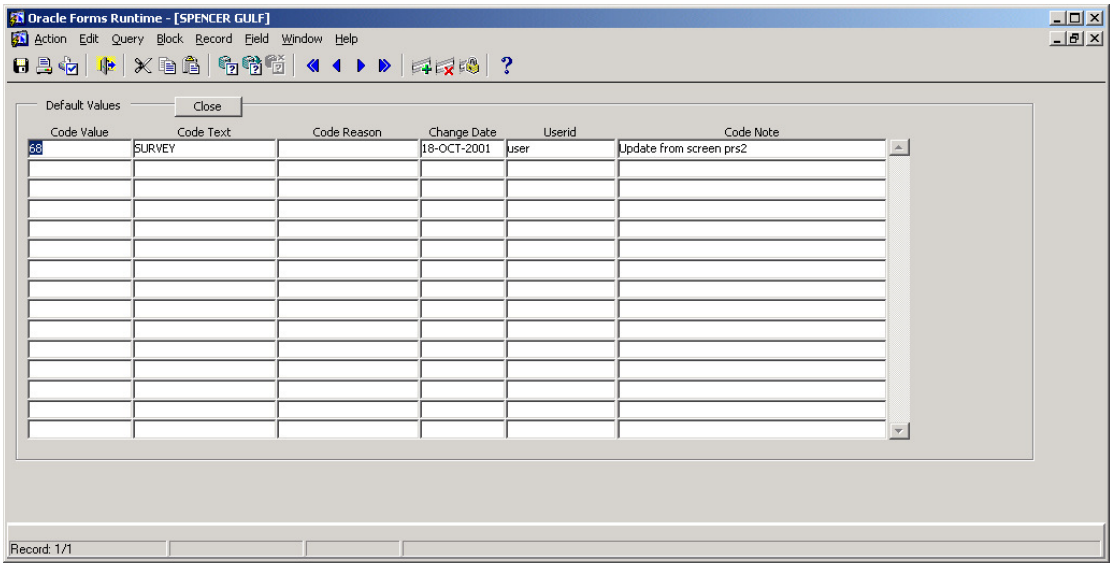


A small number of codes used in PRS.

Currently …

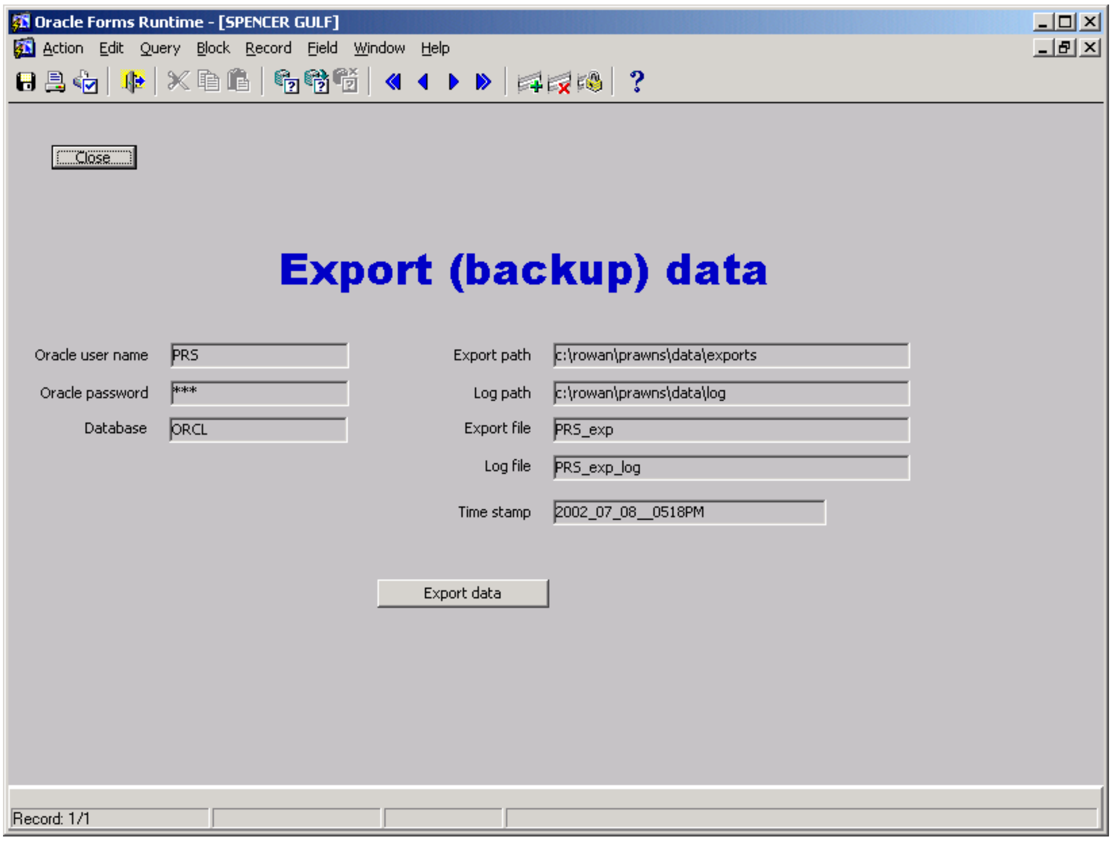
FISHERY (provides user friendly fishery name)
NONETS (number of nets used in a fishery)
STATION HIERARCHY STATUS (active, inactive)
SURVEY TYPE (sas, spot)

Default Codes



Intended to store various default values. Currently only used for default survey.

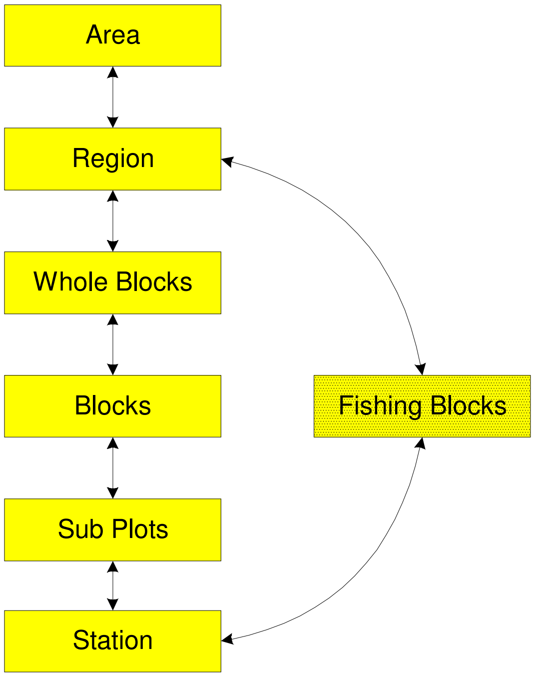
Backup Database



Manages Oracle exports (backups) which backup data in an Oracle database in an Oracle proprietary format. Note that the user must archive this backup to a safe medium to guard against PC disk failure.

Spatial Data Structure

Spatial Element Hierarchy



Note that in original data, Area means what is now Region and Region means what is now Area.

Treatment of Latitude and Longitude

Latitude and Longitude readings are held in the database as degrees, minutes and seconds.

Degrees are stored as degrees and minutes as minutes (ie 60 minutes = 1 degree).

But seconds are actually stored as the decimal fraction of a minute.

60 seconds makes one minute of latitude or longitude. But in the database we have chosen to store a value of say 30 seconds as 0.5 of a minute.

Source data from the field typically arrives is the form of 33 degrees and 44.76 minutes.

This is keyed in and stored as:

33 degrees (no minus sign)
44 minutes
76 MinFrac seconds (which could be later translated as 0.76 * 60 = 45.6 seconds)

The data entry screen actually changes the keyed in MinFrac (meaning decimal fraction of a minute) value to 3 digits for greater clarity and consistency of data entry.

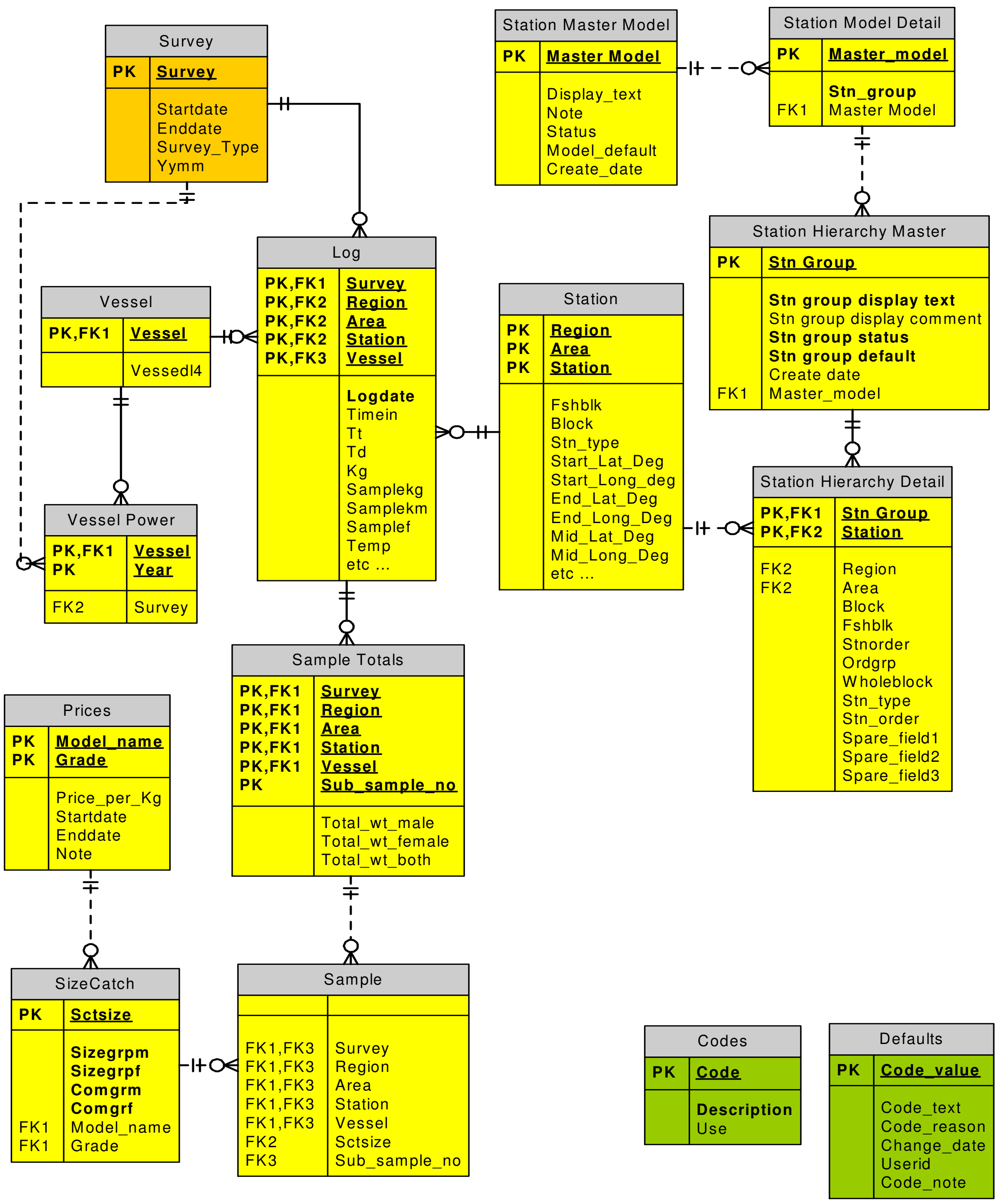
The complete sequence is:

1. Key in original data
2. Oracle screen redisplays this as 3 digits in the visible field "MinFrac" and saves it in a database field called, say, Start_Lat_Sec_Alpha
3 Oracle stores this value as a decimal fraction of a minute in a field like Start_Lat_Sec
4. Subsequent reporting could optionally translate this decimal fraction into absolute seconds

1. Original data	***2. MinFrac***	***3. Seconds***	***4. Real Seconds***
0.4	400	0.4	24
0.40	400	0.4	24
0.04	040	0.04	2.4
0.004	004	0.004	0.24

Data Structure

PRS Database Structure 13 Dec 2001



PRS TABLES

PRSDBCOD

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 CODE                          NOT NULL VARCHAR2(10)
 CODE2                                  VARCHAR2(50)
 CODE_TEXT                              VARCHAR2(50)
 CODE_REASON                            VARCHAR2(200)
 CODE_GROUP                    NOT NULL VARCHAR2(30)
```

PRSDBDFT

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 CODE_VALUE                             VARCHAR2(30)
 CODE_TEXT                              VARCHAR2(30)
 CODE_REASON                            VARCHAR2(200)
 CHANGE_DATE                            DATE
 USERID                                 VARCHAR2(32)
 CODE_NOTE                              VARCHAR2(200)
```

PRSDBLOG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 SURVEY                        NOT NULL VARCHAR2(10)
 REGION                        NOT NULL VARCHAR2(3)
 AREA                          NOT NULL VARCHAR2(6)
 STATION                       NOT NULL VARCHAR2(5)
 VESSEL                                 VARCHAR2(15)
 LOGDATE                                DATE
 TIMEIN_HRS                             NUMBER
 TIMEIN_MINS                            NUMBER
 TIMEOUT_HRS                            NUMBER
 TIMEOUT_MINS                           NUMBER
 TRAWL_MINS                             NUMBER
 TRAWL_DEPTH                            NUMBER
 TOTAL_KG                               NUMBER
 TRAWL_DISTANCE                         NUMBER
 SAMPLE_WT_KG                           NUMBER
 PRAWNS_PER_BUCKET                      NUMBER
 BUCKET_WT_KG                           NUMBER
 START_LAT_DEG                          NUMBER
 START_LAT_MIN                          NUMBER
 START_LAT_SEC                          NUMBER
 START_LONG_DEG                         NUMBER
 START_LONG_MIN                         NUMBER
 START_LONG_SEC                         NUMBER
 END_LAT_DEG                            NUMBER
 END_LAT_MIN                            NUMBER
 END_LAT_SEC                            NUMBER
 END_LONG_DEG                           NUMBER
 END_LONG_MIN                           NUMBER
 END_LONG_SEC                           NUMBER
 TRAWL_SPEED                            NUMBER
 TEMP                                   NUMBER
 BUCKETS_PORT                           NUMBER
 BUCKETS_STARBOARD                      NUMBER
 NOTE                                   VARCHAR2(500)
 DATA_ENTRY_ORDER                       NUMBER(8)
 START_LAT_SEC_ALPHA                    VARCHAR2(3)
 START_LONG_SEC_ALPHA                   VARCHAR2(3)
 END_LAT_SEC_ALPHA                      VARCHAR2(3)
 END_LONG_SEC_ALPHA                     VARCHAR2(3)
 TIMEIN_AMPM                            VARCHAR2(2)
 TIMEOUT_AMPM                           VARCHAR2(2)
 TIDE_CODE                              VARCHAR2(5)
```

PRSDBMAD

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 MASTER_MODEL                  NOT NULL VARCHAR2(5)
 STN_GROUP                     NOT NULL VARCHAR2(5)
```

PRSDBMAM

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 MASTER_MODEL                  NOT NULL VARCHAR2(5)
 DISPLAY_TEXT                           VARCHAR2(100)
 NOTE                                   VARCHAR2(2000)
 STATUS                                 VARCHAR2(10)
 MODEL_DEFAULT                          VARCHAR2(3)
 CREATE_DATE                            DATE
```

PRSDBPRI

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 MODEL_NAME                    NOT NULL VARCHAR2(30)
 GRADE                         NOT NULL VARCHAR2(6)
 PRICE_PER_KG                           NUMBER
 STARTDATE                              DATE
 ENDDATE                                DATE
 NOTE                                   VARCHAR2(200)
 RANGE_HI                               NUMBER
 RANGE_LO                               NUMBER
```

PRSDBSAM

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 SURVEY                        NOT NULL VARCHAR2(10)
 REGION                        NOT NULL VARCHAR2(3)
 AREA                          NOT NULL VARCHAR2(2)
 STATION                       NOT NULL VARCHAR2(5)
 SAMSIZE                       NOT NULL NUMBER
 MALES                                  NUMBER
 FEMALES                                NUMBER
 SUB_SAMPLE_NO                 NOT NULL NUMBER(2)
```

PRSDBSAT

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 SURVEY                        NOT NULL VARCHAR2(10)
 REGION                        NOT NULL VARCHAR2(3)
 AREA                          NOT NULL VARCHAR2(2)
 STATION                       NOT NULL VARCHAR2(5)
 TOTAL_WT_MALE                          NUMBER
 TOTAL_WT_FEMALE                        NUMBER
 TOTAL_WT_BOTH                          NUMBER
 SUB_SAMPLE_NO                 NOT NULL NUMBER(2)
```

PRSDBSCT

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 SCTSIZE                       NOT NULL NUMBER
 MGRAM                                  NUMBER
 MNO_LB                                 NUMBER
 MGRADE                                 VARCHAR2(6)
 MRANGE                                 VARCHAR2(6)
 FGRAM                                  NUMBER
 FNO_LB                                 NUMBER
 FGRADE                                 VARCHAR2(6)
 FRANGE                                 VARCHAR2(6)
 GRP2_GRADE                             VARCHAR2(6)
 GRP2_MRANGE                            VARCHAR2(6)
 GRP2_FRANGE                            VARCHAR2(6)
 GRP3_GRADE                             VARCHAR2(6)
 GRP3_MRANGE                            VARCHAR2(6)
 GRP3_FRANGE                            VARCHAR2(6)
 MRANGE_HI                              NUMBER
 MRANGE_LO                              NUMBER
 FRANGE_HI                              NUMBER
 FRANGE_LO                              NUMBER
 GRP2_MRANGE_HI                         NUMBER
 GRP2_MRANGE_LO                         NUMBER
 GRP2_FRANGE_HI                         NUMBER
 GRP2_FRANGE_LO                         NUMBER
 GRP3_MRANGE_HI                         NUMBER
 GRP3_MRANGE_LO                         NUMBER
 GRP3_FRANGE_HI                         NUMBER
 GRP3_FRANGE_LO                         NUMBER
```

PRSDBSHD

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 STN_GROUP                     NOT NULL VARCHAR2(5)
 AREA                          NOT NULL VARCHAR2(6)
 REGION                        NOT NULL VARCHAR2(3)
 WHOLEBLOCK                             VARCHAR2(3)
 BLOCK                                  VARCHAR2(3)
 SUBPLOT                                VARCHAR2(3)
 FSHBLK                                 VARCHAR2(3)
 STATION                       NOT NULL VARCHAR2(5)
 ORDGRP                                 VARCHAR2(3)
 STN_TYPE                               VARCHAR2(10)
 STN_ORDER                              NUMBER(5)
 SPARE_FIELD1                           VARCHAR2(5)
 SPARE_FIELD2                           VARCHAR2(5)
 SPARE_FIELD3                           VARCHAR2(5)
 NOTE                                   VARCHAR2(200)
```

PRSDBSHM

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 STN_GROUP                     NOT NULL VARCHAR2(5)
 STN_GROUP_DISPLAY_TEXT                 VARCHAR2(200)
 STN_GROUP_DISPLAY_COMMENT              VARCHAR2(2000)
 STN_GROUP_STATUS                       VARCHAR2(10)
 STN_GROUP_DEFAULT                      VARCHAR2(3)
 CREATE_DATE                            DATE
```

PRSDBSRV

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 SURVEY                        NOT NULL VARCHAR2(10)
 STARTDATE                              DATE
 ENDDATE                                DATE
 SURVEY_TYPE                            VARCHAR2(10)
 YYMM                                   VARCHAR2(4)
 ALT_NAME                               VARCHAR2(15)
```

PRSDBSTN

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 REGION                        NOT NULL VARCHAR2(3)
 AREA                          NOT NULL VARCHAR2(6)
 STATION                       NOT NULL VARCHAR2(5)
 FSHBLK                                 VARCHAR2(3)
 BLOCK                                  VARCHAR2(3)
```

```
 STN_TYPE                                VARCHAR2(10)
 START_LAT_DEG                           NUMBER
 START_LAT_MIN                           NUMBER
 START_LAT_SEC                           NUMBER
 START_LONG_DEG                          NUMBER
 START_LONG_MIN                          NUMBER
 START_LONG_SEC                          NUMBER
 END_LAT_DEG                             NUMBER
 END_LAT_MIN                             NUMBER
 END_LAT_SEC                             NUMBER
 END_LONG_DEG                            NUMBER
 END_LONG_MIN                            NUMBER
 END_LONG_SEC                            NUMBER
 MID_LAT_DEG                             NUMBER
 MID_LAT_MIN                             NUMBER
 MID_LAT_SEC                             NUMBER
 MID_LONG_DEG                            NUMBER
 MID_LONG_MIN                            NUMBER
 MID_LONG_SEC                            NUMBER
```

PRSDBVEM

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                         NOT NULL VARCHAR2(10)
 VESSEL                         NOT NULL VARCHAR2(15)
 POWER_INDEX_NO                 NOT NULL NUMBER
 POWER_INDEX_VALUE                       NUMBER
 DISPLAY_TEXT                            VARCHAR2(100)
 NOTE                                    VARCHAR2(200)
 CREATE_DATE                             DATE
```

PRSDBVEP

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                         NOT NULL VARCHAR2(10)
 VESSEL                         NOT NULL VARCHAR2(15)
 POWER_INDEX1                            NUMBER
 POWER_INDEX2                            NUMBER
 POWER_INDEX3                            NUMBER
 NOTE                                    VARCHAR2(200)
```

PRSDBVES

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 VESSEL                         NOT NULL VARCHAR2(15)
 VESSEL_SHORTNAME                        VARCHAR2(10)
 VESSEL_SHORTNAME2                       VARCHAR2(10)
 VESSEL_SHORTNAME3                       VARCHAR2(10)
 VESSEL_LICENCE_NO                       VARCHAR2(15)
```

PRS>
REP_CSKG

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(10)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 CSKG                                    NUMBER
```

REP_NT6

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(4)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 MRECNM                                  NUMBER
 FRECNM                                  NUMBER
 MRECNM_B                                NUMBER
 FRECNM_B                                NUMBER
 RECRNM                                  NUMBER
 PCT_RECNM                               NUMBER
 TOT_RECNM                               NUMBER
 TOT_KGNM                                NUMBER
 RC                                      NUMBER
 CTNO                                    NUMBER
 TD                                      NUMBER
 GR1                                     VARCHAR2(5)
 GR2                                     VARCHAR2(5)
 COMGRADE                                VARCHAR2(6)
```

REP_NT6A

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(10)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 MRECNM                                  NUMBER
 FRECNM                                  NUMBER
 RECNM                                   NUMBER
 TOTNM                                   NUMBER
 RC                                      NUMBER
```

REP_NT6_A

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(4)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 MRECNM                                  NUMBER
```

REP_NT6_B

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(4)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 FRECNM                                  NUMBER
```

REP_NT6_C

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(4)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 TOT_RECNM                               NUMBER
 TOT_KGNM                                NUMBER
```

REP_NT6_COMGRADE

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(4)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 COMGRADE                                VARCHAR2(6)
 SAMSIZE                                 NUMBER
 SEX                                     VARCHAR2(1)
 NO                                      NUMBER
```

REP_NT6_D

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(4)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 RC                                      NUMBER
```

REP_NT6_E

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(4)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 MRECNM                                  NUMBER
```

REP_NT6_F

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(4)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 FRECNM                                  NUMBER
```

REP_SFN

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 SURVEY                                  VARCHAR2(10)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 SAMSIZE                                 NUMBER
 SEX                                     VARCHAR2(1)
 NO                                      NUMBER
 CTNO                                    NUMBER
 TOTAL_KG                                NUMBER
 SKG                                     NUMBER
 CTKG                                    NUMBER
 COMGRADE                                VARCHAR2(6)
```

REP_SSS

```
 Name                           Null?    Type
------------------------------ -------- ------------------
-
 SURVEY                                  VARCHAR2(10)
 AREA                                    VARCHAR2(6)
 REGION                                  VARCHAR2(3)
 STATION                                 VARCHAR2(5)
 TOTAL_KG                                NUMBER
 SKG                                     NUMBER
 SAMPLE_WT_KG                            NUMBER
```

PRS INDEXES

TABLE_NAME	C	CONSTRAINT_NAME	col_name	STATUS
------------------------------	-	------------------------------	------------------------------	--------
PRSDBCOD	P	SYS_C0015027	CODE	ENABLED
			CODE_GROUP	ENABLED
PRSDBDAY	P	PK_SRV_DAY	DAY	ENABLED
			SURVEY	ENABLED
	R	FK_SRV_DAY	SURVEY	ENABLED
PRSDBLOG	P	SYS_C0015039	AREA	ENABLED
			REGION	ENABLED
			STATION	ENABLED
			SURVEY	ENABLED
	R	SYS_C0015040	SURVEY	ENABLED
		SYS_C0015041	AREA	ENABLED
			REGION	ENABLED
			STATION	ENABLED
		SYS_C0015042	VESSEL	ENABLED
		SYS_C0015255	SURVEY	ENABLED
			VESSEL	ENABLED
PRSDBMAD	P	SYS_C0015056	MASTER_MODEL	ENABLED
			STN_GROUP	ENABLED
	R	SYS_C0015057	MASTER_MODEL	ENABLED
		SYS_C0015058	STN_GROUP	ENABLED
PRSDBMAM	P	SYS_C0015055	MASTER_MODEL	ENABLED
PRSDBPRI	P	SYS_C0015249	GRADE	ENABLED
			MODEL_NAME	ENABLED
PRSDBSAM	P	SYS_C0015043	AREA	ENABLED
			REGION	ENABLED
			SAMSIZE	ENABLED
			STATION	ENABLED
			SUB_SAMPLE_NO	ENABLED
			SURVEY	ENABLED
	R	SYS_C0015044	AREA	ENABLED
			REGION	ENABLED
			STATION	ENABLED
			SURVEY	ENABLED
		SYS_C0015045	SURVEY	ENABLED
		SYS_C0015286	AREA	ENABLED
			REGION	ENABLED
			STATION	ENABLED
			SUB_SAMPLE_NO	ENABLED
			SURVEY	ENABLED

		SYS_C0017014	SAMSIZE	ENABLED
PRSDBSAT	P	SYS_C0015282	AREA	ENABLED
			REGION	ENABLED
			STATION	ENABLED
			SUB_SAMPLE_NO	ENABLED
			SURVEY	ENABLED
	R	SYS_C0015283	AREA	ENABLED
			REGION	ENABLED
			STATION	ENABLED
			SURVEY	ENABLED
		SYS_C0015284	SURVEY	ENABLED
PRSDBSCT	P	SYS_C0015015	SCTSIZE	ENABLED
PRSDBSHD	P	SYS_C0015035	AREA	ENABLED
			REGION	ENABLED
			STATION	ENABLED
			STN_GROUP	ENABLED
	R	SYS_C0015034	STN_GROUP	ENABLED
PRSDBSHM	P	SYS_C0015024	STN_GROUP	ENABLED
PRSDBSRV	P	SYS_C0015010	SURVEY	ENABLED
PRSDBSTN	P	SYS_C0015016	AREA	ENABLED
			REGION	ENABLED
			STATION	ENABLED
PRSDBVEM	P	SYS_C0015251	POWER_INDEX_NO	ENABLED
			SURVEY	ENABLED
			VESSEL	ENABLED
	R	SYS_C0015250	SURVEY	ENABLED
			VESSEL	ENABLED
PRSDBVEP	P	SYS_C0015012	SURVEY	ENABLED
			VESSEL	ENABLED
	R	SYS_C0015013	VESSEL	ENABLED
		SYS_C0015014	SURVEY	ENABLED
PRSDBVES	P	SYS_C0015011	VESSEL	ENABLED
PRS_FBLOCK	P	SYS_C0016223	FSHBLK	ENABLED
PRS_REP_STATUS_FILTER	P	PK_PRS_REP_STATUS_FILTER	CODE	ENABLED
			CODE_TYPE	ENABLED
			CODE_VALUE	ENABLED
			REPORT_NAME	ENABLED
	R	FK_REP_STATUS_FILTER_REP	REPORT_NAME	ENABLED
PRS_REP_STATUS_REP	P	PK_PRS_REP_STATUS_REP	REPORT_NAME	ENABLED

PRS_REP_STATUS_SURVEY	P	PK_PRS_REP_STATUS_SURVEY	REPORT_NAME	ENABLED
			SURVEY	ENABLED
			TABLE_NAME	ENABLED
	R	FK_REP_STATUS_SURVEY_TAB	REPORT_NAME	ENABLED
			TABLE_NAME	ENABLED
PRS_REP_STATUS_TAB	P	PK_PRS_REP_STATUS_TAB	REPORT_NAME	ENABLED
			TABLE_NAME	ENABLED
	R	FK_REP_STATUS_TAB_REP	REPORT_NAME	ENABLED

STATION DATA

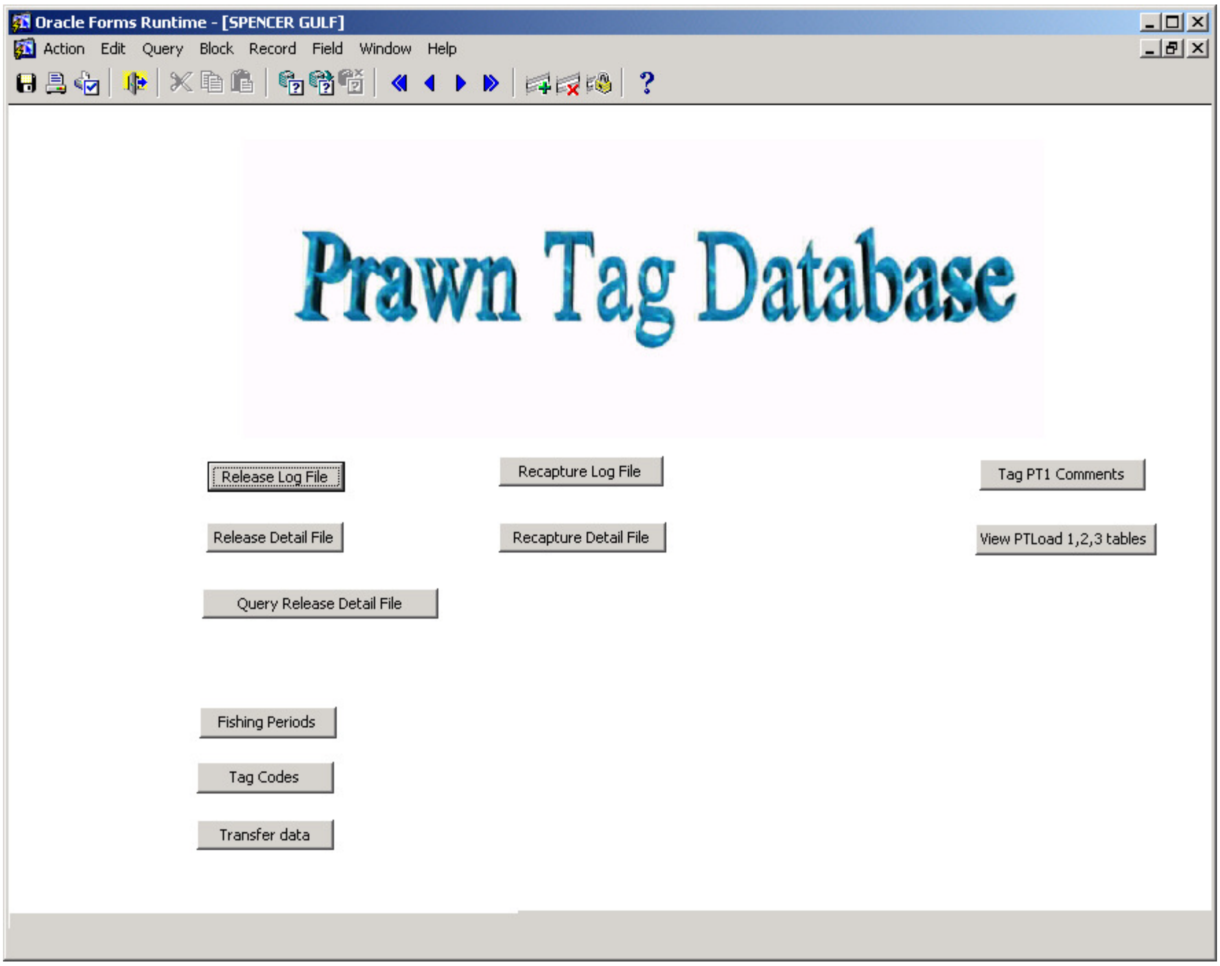
Original Grouping

AREA	REGION	NAME	STATIONS
01	1	**NORTHERN SPENCER GULF**	
	2	? Broughton	
	3	Wallaroo	
	4	Gutter – main	
	5	Cowell Zone 1	
	6	Cowell Zone 2	
	7	Cowell Zone 3	
	8	Cowell Zone 4	
	9	Corny Pt	C1 ..C14
	10	Western Gutter	CP1 ..CP6
04	1	Venus Bay	V01..V26
	2	Ceduna	C01..C17

Tag database and Catch Monitoring System

TAG Main Menu

Screen Title	Purpose	Form name
Release Log File	Enter Logged release data	Pt_release_log
Release Detail File	Enter detailed release data	Pt_release_detail
Release detail query	Release detail query	Pt_rel_detail_query
Recapture Log File	Enter logged recapture data	Pt_recap_log
Recapture Detail File	Enter detailed recapture data	Pt_recap_detail
Tag PT1 Comments	Obsolete	
View PTLoad 1,2,3 Tables	Obsolete	
Query Release Detail File	Query release details	
Fishing Periods	Enter fishing periods	
Tag Codes	Enter codes	
Transfer Data	?	?
Close	NDYet	



TAG data

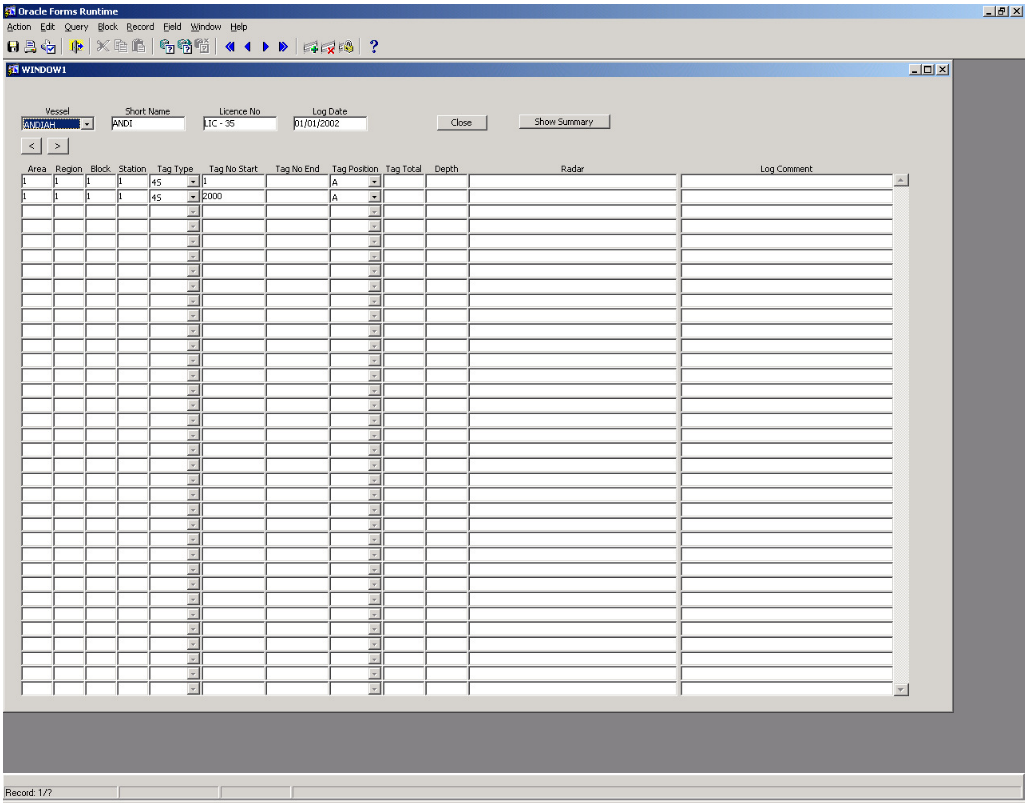
TAG Data tables

PT_CODE	Codes used in TAG application.
PT_FISHING_PERIODS	Fishing period definitions.
PT_LOG	
PT_RECAPTURE1	Recapture details.
PT_RECAPTURE2	Recapture log details table.
PT_RECAPTURE2M	Recapture log parent table.
PT_RELEASE1	Release details.
PT_RELEASE2	Release details.
PT_RELEASELD	Release log details table.
PT_RELEASELM	Release log parent table.

TAG Forms

Form name:	pt_main
Base table:	n/a
Unique key:	n/a

Release_Log_File



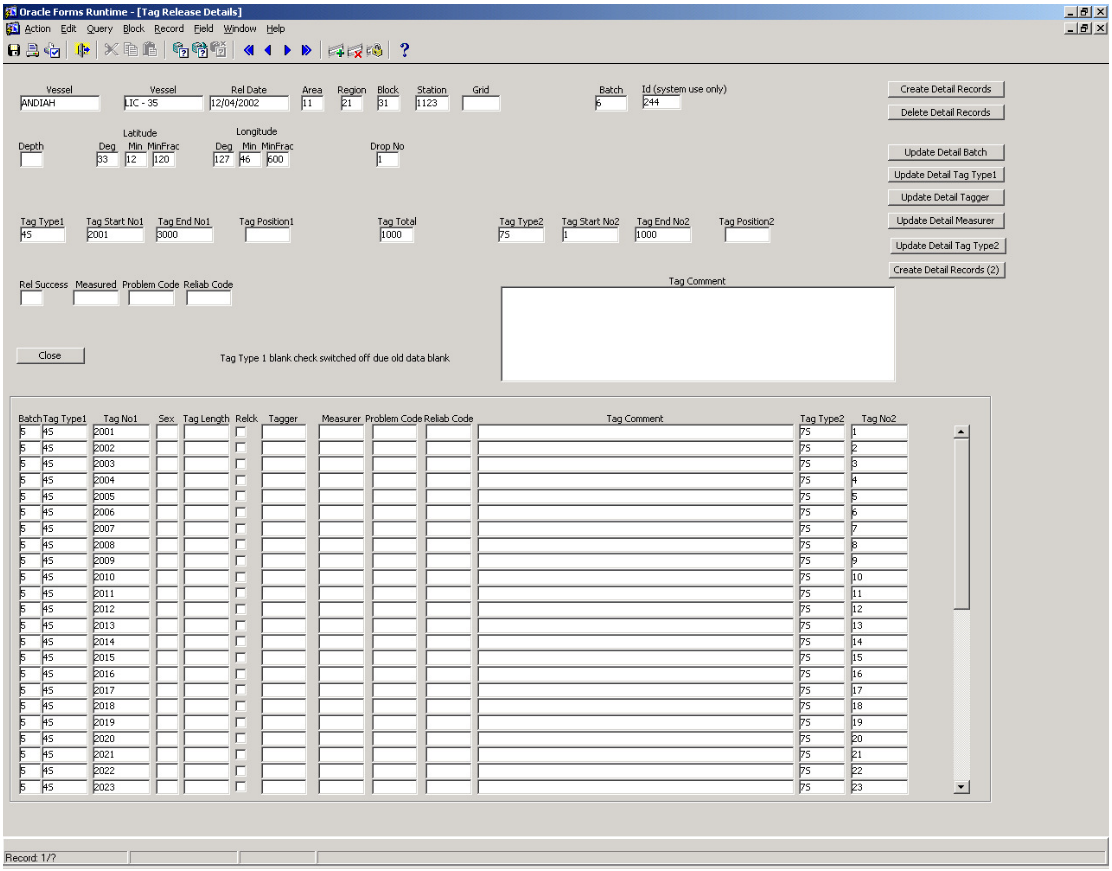
Form name: PT_RELEASE_LOG
Base table: PT_RELEASELM
PT_RELEASELD
Unique key: LM.Vessel, LM.Log_Date, LD.Vessel, LD.Log_Date, LD.Area, LD.Region, LD.Station, LD.Tag_type, LD.Tag_No_Start

FIELDS

Screen name	Real name	Base Table	Note
Vessel	VESSEL	PT_RELEASEM	
Short_name	SHORT_NAME	"	
Licence_no	LICENCE_NO	"	
Log_date	LOG_DATE	"	
Area	AREA	PT_RELEASED	
Region	REGION	"	
Block	BLOCK	"	
Station	STATION	"	
Tag Type	TAG_TYPE	"	
Tag No Start	TAG_NO_START	"	
Tag No End	TAG _NO_END	"	
Tag Position	TAG_POSITION	"	
Tag Total	TAG_TOTAL	"	
Depth	DEPTH	"	
Radar	RADAR	"	
Log Comment	LOG_COMMENT	"	

Shows the summary log entry for a batch of tag releases in a continuous numeric series for each release event.

Release Detail File



Form name: PT_RELEASE_DETAIL
Base table: PT_RELEASE2 (parent)
PT_RELEASE1 (child)
Unique key: 2.vessel, 2. rel_date, 2.id
1.vessel, 1.rel_date, 1.id

FIELDS

Screen name	Real name	Base Table	Note
Vessel		PT_RELEASE2	
Licence_no		“	
Rel_date		“	
Area		“	
Region		“	
Block		“	
Station		“	
Grid		“	
Depth		“	
Lat Deg		“	
Lat Min		“	
Lat Minfrac		“	
Long Deg		“	
Long Min		“	
Long Minfrac		“	
Drop No		“	
Tag Type1		“	

Tag Start No1		"	
Tag End No1		"	
Tag Position1		"	
Tag Total		"	
Tag Type2		"	
Tag Start No2		"	
Tag End No2		"	
Tag Position2		"	
Rel Success		"	
Measured		"	
Problem Code		"	
Reliab Code		"	
Tag Comment		"	
Batch		PT_RELEASE1	
Tag Type1		"	
Tag No1		"	
Sex		"	
Tag Length		"	
Relck		"	
Tagger		"	
Measurer		"	
Problem Code		"	
Reliab Code		"	
Tag Comment		"	
Tag Type2		"	
Tag No2		"	

Captures details of each tag release.

The "Enter Double Tag details" buttons displays the otherwise hidden fields in the top half of the screen to allow entry of data in cases where prawns were double tagged.

The "Update … " buttons allow automatic updating of the respective field (in the bottom half of the screen) of all subsequent rows. This provides an easy way to bulk update taggers for example when they change mid way through a batch of records.

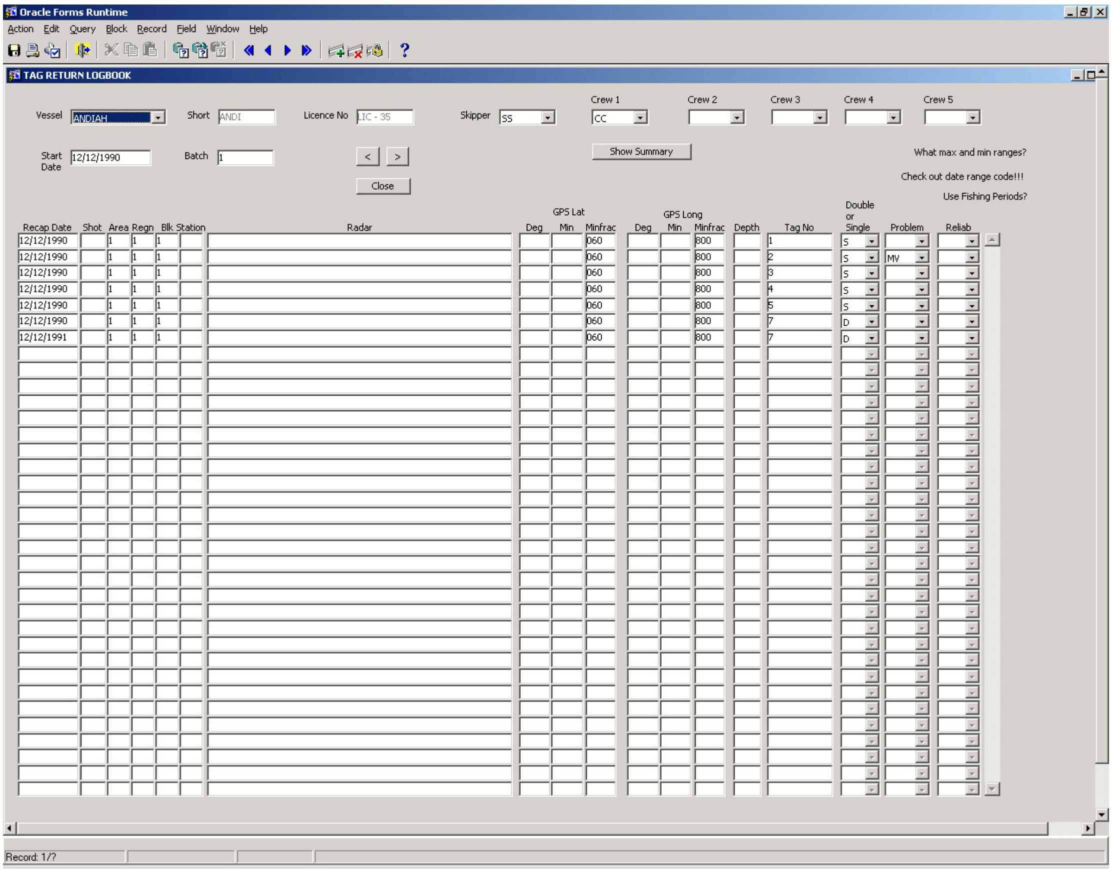
The "Tag No1 ?" and "Tag No 2?" buttons list all tag numbers in order in case you need to see all tag numbers entered into the application so far.

The "Fix Details" button should not be needed. It was used to ensure that all detail records had the correct area, region, block and station details to match those of the parent record in the top half of the screen. This should happen normally anyway.

The "Create Detail Records" button is used after entry of the top half screen is finalised and you are ready to create the matching detail records. The "Create Details Records 2" button is necessary because it is used to manually populate fields where 2 tags have been used (as entered in the top half of the screen).

The "Delete Detail Records" button can be used at any time when it is required to delete the details in the bottom half of the screen (for the tag series currently showing in the top half of the screen).

Recapture Log File



Form name: PT_RECAP_LOG
Base table: PT_RECAPTURE2M
PT_RECAPTURE2
Unique key: 2M.Vessel, 2M.Start_Date
2.Vessel, 2.Start_Date, 2.Recapture_Date, 2. Fishblk, 2.Tag_No

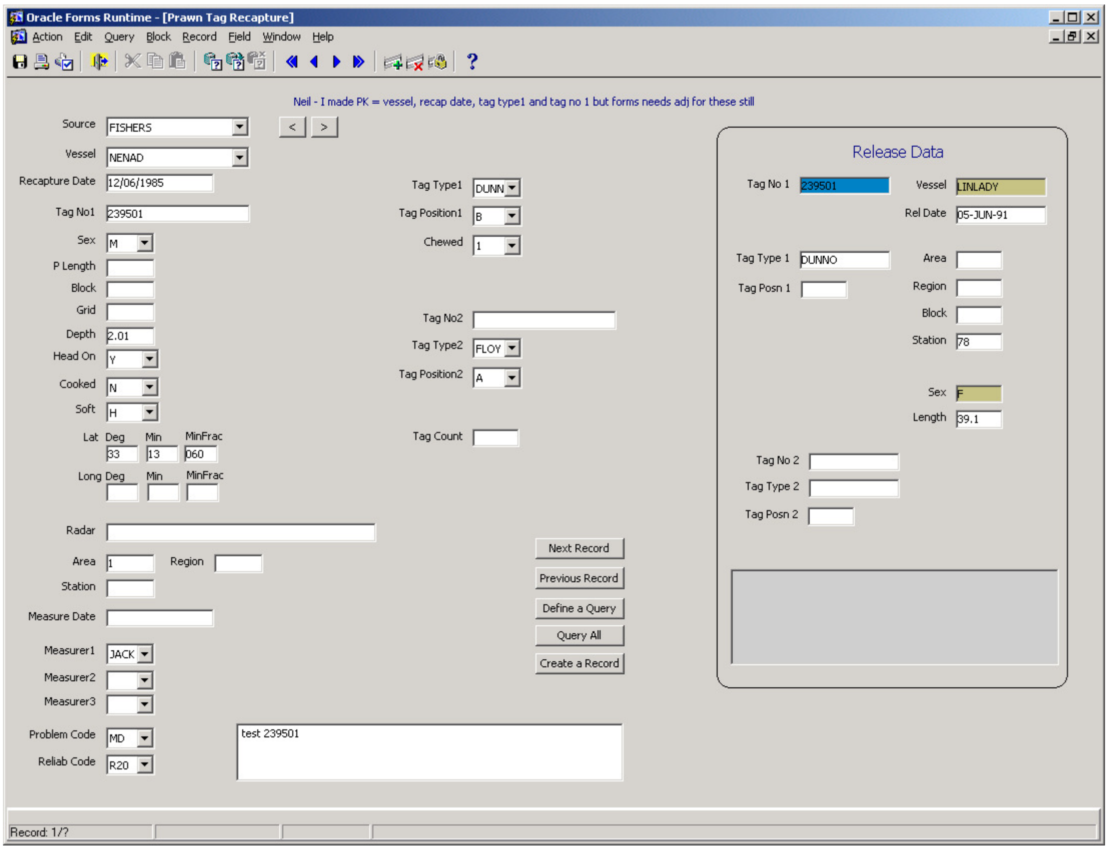
FIELDS

Screen name	Real name	Base Table	Note
Vessel		PT_RECAPTURE2M	
Vessel_shortname		"	
Vessel_licence_no		"	
Start_date		"	
Batch		"	
Skipper		"	
Crew1		"	
Crew2		"	
Crew3		"	
Crew4		"	
Crew5		"	
Recap_Date		PT_RECAPTURE2	
Shot		"	
Area		"	
Region		"	

Blk		"	
Station		"	
Radar		"	
Gps_lat_deg		"	
Gps_lat_min		"	
Gps_lat_Minfrac	Gps_lat_sec_alpha	"	
Gps_long_deg		"	
Gps_long_min		"	
Gps_long_Minfrac	Gps_long_sec_alpha	"	
Depth		"	
Tag_No		"	
Double or Single	Tag_Single	"	
Problem	Problem_Code	"	
Reliab	Reliab_code	"	

This form stores a log record of the recaptures tagged prawn.

Recapture Detail File

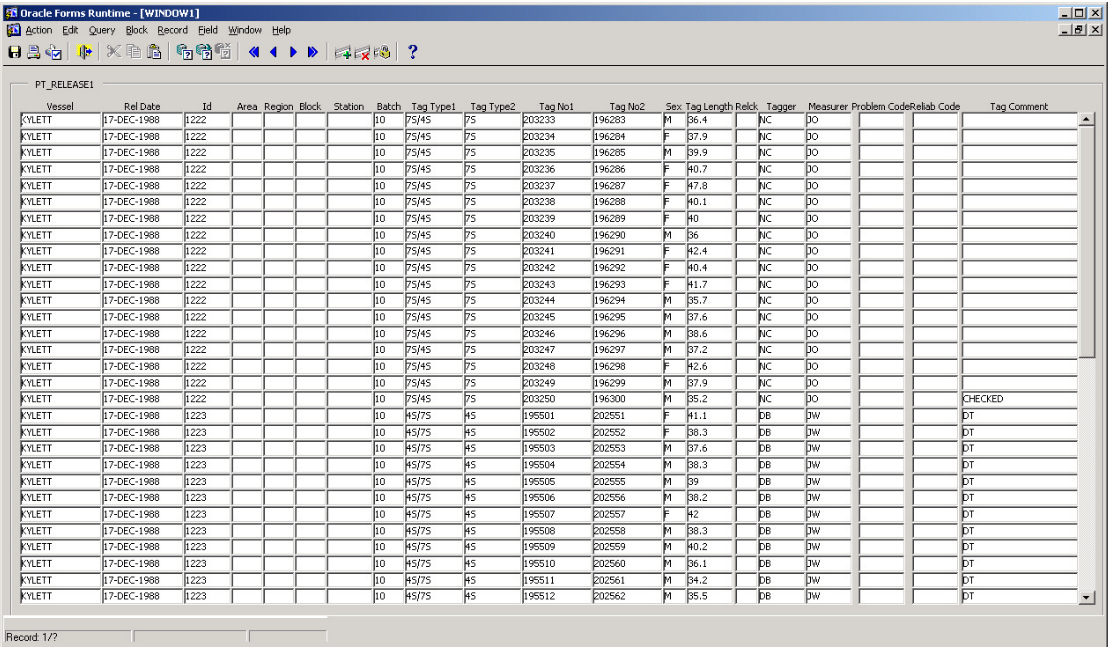


Form name: PT_RECAP_DETAIL
Base table: PT_RECAPTURE1
Unique key: Vessel, Recapture_date, Tag_no1, Tag_type1

Screen name	Real name	Base Table	Note
Source		PT_RECAPTURE1	
Batch		"	
Vessel		"	
Recapture_Date		"	
Tag_no1		"	
Sex		"	
P_Length		"	
Block		"	
Grid		"	
Depth		"	
Depth_Fathoms		"	Derived from depth if it exists
Head_on		"	
Cooked		"	
Soft		"	
Lat Deg		"	
Lat Min		"	
Lat MinFrac		"	
Long Deg		"	
Long Min		"	
Long MinFrac		"	
Radar		"	
Area		"	

Region		“	
Station		“	
Measure_date		“	
Measurer1		“	
Measurer2		“	
Measurer3		“	
Problem_code		“	
Reliab_code		“	
Tag_Type1		“	
Tag_Position1		“	
Chewed		“	
Tag_no2		“	
Tag_type2		“	
Tag_position2		“	
Tag_count		“	
Recap_Comment		“	
The other fields are derived from release data			

Query Release Detail File


Oracle Forms Runtime - [WINDOW1]
Action Edit Query Block Record Field Window Help
PT_RELEASE1

Vessel	Rel Date	Id	Area	Region	Block	Station	Batch	Tag Type1	Tag Type2	Tag No1	Tag No2	Sex	Tag Length	Relck	Tagger	Measurer	Problem Code	Reliab Code	Tag Comment
KYLETT	17-DEC-1988	1222					10	75/45	75	203233	196283	M	36.4		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203234	196284	F	37.9		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203235	196285	M	39.9		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203236	196286	F	40.7		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203237	196287	F	47.8		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203238	196288	F	40.1		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203239	196289	F	40		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203240	196290	M	36		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203241	196291	F	42.4		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203242	196292	F	40.4		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203243	196293	F	41.7		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203244	196294	M	35.7		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203245	196295	M	37.6		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203246	196296	M	38.6		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203247	196297	M	37.2		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203248	196298	F	42.6		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203249	196299	M	37.9		NC	JO			
KYLETT	17-DEC-1988	1222					10	75/45	75	203250	196300	M	35.2		NC	JO			CHECKED
KYLETT	17-DEC-1988	1223					10	45/75	45	195501	202551	F	41.1		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195502	202552	F	38.3		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195503	202553	M	37.6		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195504	202554	M	38.3		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195505	202555	M	39		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195506	202556	M	38.2		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195507	202557	F	42		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195508	202558	M	38.3		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195509	202559	M	40.2		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195510	202560	M	36.1		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195511	202561	M	34.2		DB	JW			DT
KYLETT	17-DEC-1988	1223					10	45/75	45	195512	202562	M	35.5		DB	JW			DT

Record: 1/?

Form name: PT_RELEASE_DETAIL_QRY
Base table: PT_RELEASE1
Unique key: vessel, rel_date, id

This form is intended to view data rather than edit it. It displays all release detail records or those filtered by any search criteria. It exists because the main data entry form cannot really be used to search for one or more specific single release detail records.

Reports

List_releases2.sql

```
break on id nodup

set linesize 500

spool list_releases.txt

select  rel_date,  batch,  id,    vessel,  tag_type1,  tag_start_no1,    tag_type2,
tag_start_no2, tag_total,
drop_no,
area, region, block, station,
substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15) "LAT",
substr(r.long_deg||' '||r.long_min||r.long_sec,1,15) "LONG"
from pt_release2 r
order by 1,2,3,4;


spool off

spool list_releases2.txt

-- Match release detail tag1 with recapture detail tag1

select   r.rel_date,   r.batch,   r.id,     r.vessel,   r.tag_type1,   tag_start_no1,
r.tag_type2, tag_start_no2, tag_total,
drop_no,
r.area, r.region, r.block, r.station,
decode(
       case when r.lat_deg is null then 'NULL'
       when r.lat_min is null then 'NULL'
       when r.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.lat_deg||' '||fb.lat_min||fb.lat_sec,1,15),
        substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15)
      )    "REL LAT",
decode(
       case when r.long_deg is null then 'NULL'
       when r.long_min is null then 'NULL'
       when r.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.long_deg||' '||fb.long_min||fb.long_sec,1,15),
        substr(r.long_deg||' '||r.long_min||r.long_sec,1,15)
      )    "REL LONG",
count(c.tag_no1),
c.block "RECAP BLOCK",
decode(
       case when c.lat_deg is null then 'NULL'
       when c.lat_min is null then 'NULL'
       when c.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.lat_deg||' '||fb2.lat_min||fb2.lat_sec,1,15),
        substr(c.lat_deg||' '||c.lat_min||c.lat_sec,1,15)
      )    "RECAP LAT",
decode(
       case when c.long_deg is null then 'NULL'
       when c.long_min is null then 'NULL'
       when c.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.long_deg||' '||fb2.long_min||fb2.long_sec,1,15),
        substr(c.long_deg||' '||c.long_min||c.long_sec,1,15)
      )    "RECAP LONG"
from pt_release2 r, pt_recapture1 c, pt_release1 r1, prs_fblock fb, prs_fblock fb2
where r1.tag_no1 = c.tag_no1(+)
and r.id = r1.id
and r.vessel = r1.vessel
and r.batch  = r1.batch
and r.rel_date = r1.rel_date
and r.block = fb.fshblk(+)
and c.block = fb2.fshblk(+)
group  by  r.rel_date,  r.batch,  r.id,    r.vessel,  r.tag_type1,  tag_start_no1,
r.tag_type2, tag_start_no2, tag_total,
drop_no,
r.area, r.region, r.block, r.station,
```

```
decode(
       case when r.lat_deg is null then 'NULL'
       when r.lat_min is null then 'NULL'
       when r.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.lat_deg||' '||fb.lat_min||fb.lat_sec,1,15),
        substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15)
      ),
decode(
       case when r.long_deg is null then 'NULL'
       when r.long_min is null then 'NULL'
       when r.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.long_deg||' '||fb.long_min||fb.long_sec,1,15),
        substr(r.long_deg||' '||r.long_min||r.long_sec,1,15)
      ),
c.block,
decode(
       case when c.lat_deg is null then 'NULL'
       when c.lat_min is null then 'NULL'
       when c.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.lat_deg||' '||fb2.lat_min||fb2.lat_sec,1,15),
        substr(c.lat_deg||' '||c.lat_min||c.lat_sec,1,15)
      ),
decode(
       case when c.long_deg is null then 'NULL'
       when c.long_min is null then 'NULL'
       when c.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.long_deg||' '||fb2.long_min||fb2.long_sec,1,15),
        substr(c.long_deg||' '||c.long_min||c.long_sec,1,15)
      )
order by 1,2,3,4;

-- Match release detail tag1 with recapture detail tag2

select   r.rel_date,   r.batch,   r.id,     r.vessel,   r.tag_type1,   tag_start_no1,
r.tag_type2, tag_start_no2, tag_total,
drop_no,
r.area, r.region, r.block, r.station,
decode(
       case when r.lat_deg is null then 'NULL'
       when r.lat_min is null then 'NULL'
       when r.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.lat_deg||' '||fb.lat_min||fb.lat_sec,1,15),
        substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15)
      )    "REL LAT",
decode(
       case when r.long_deg is null then 'NULL'
       when r.long_min is null then 'NULL'
       when r.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.long_deg||' '||fb.long_min||fb.long_sec,1,15),
        substr(r.long_deg||' '||r.long_min||r.long_sec,1,15)
      )    "REL LONG",
count(c.tag_no1),
c.block "RECAP BLOCK",
decode(
       case when c.lat_deg is null then 'NULL'
       when c.lat_min is null then 'NULL'
       when c.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.lat_deg||' '||fb2.lat_min||fb2.lat_sec,1,15),
        substr(c.lat_deg||' '||c.lat_min||c.lat_sec,1,15)
      )    "RECAP LAT",
decode(
       case when c.long_deg is null then 'NULL'
       when c.long_min is null then 'NULL'
       when c.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.long_deg||' '||fb2.long_min||fb2.long_sec,1,15),
        substr(c.long_deg||' '||c.long_min||c.long_sec,1,15)
      )    "RECAP LONG"
from pt_release2 r, pt_recapture1 c, pt_release1 r1, prs_fblock fb, prs_fblock fb2
where  r1.tag_no1 = c.tag_no2
and r.id = r1.id
and r.vessel = r1.vessel
and r.batch  = r1.batch
```

```
and r.rel_date = r1.rel_date
and r.block = fb.fshblk(+)
and c.block = fb2.fshblk(+)
group by r.rel_date, r.batch, r.id,  r.vessel, r.tag_type1, tag_start_no1,
r.tag_type2, tag_start_no2, tag_total,
drop_no,
r.area, r.region, r.block, r.station,
decode(
       case when r.lat_deg is null then 'NULL'
       when r.lat_min is null then 'NULL'
       when r.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.lat_deg||' '||fb.lat_min||fb.lat_sec,1,15),
        substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15)
      ),
decode(
       case when r.long_deg is null then 'NULL'
       when r.long_min is null then 'NULL'
       when r.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.long_deg||' '||fb.long_min||fb.long_sec,1,15),
        substr(r.long_deg||' '||r.long_min||r.long_sec,1,15)
      ),
c.block,
decode(
       case when c.lat_deg is null then 'NULL'
       when c.lat_min is null then 'NULL'
       when c.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.lat_deg||' '||fb2.lat_min||fb2.lat_sec,1,15),
        substr(c.lat_deg||' '||c.lat_min||c.lat_sec,1,15)
      ),
decode(
       case when c.long_deg is null then 'NULL'
       when c.long_min is null then 'NULL'
       when c.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.long_deg||' '||fb2.long_min||fb2.long_sec,1,15),
        substr(c.long_deg||' '||c.long_min||c.long_sec,1,15)
      )
order by 1,2,3,4;


-- Match release detail tag2 with recapture detail tag1

select r.rel_date, r.batch, r.id,  r.vessel, r.tag_type1, tag_start_no1,
r.tag_type2, tag_start_no2, tag_total,
drop_no,
r.area, r.region, r.block, r.station,
decode(
       case when r.lat_deg is null then 'NULL'
       when r.lat_min is null then 'NULL'
       when r.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.lat_deg||' '||fb.lat_min||fb.lat_sec,1,15),
        substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15)
      )    "REL LAT",
decode(
       case when r.long_deg is null then 'NULL'
       when r.long_min is null then 'NULL'
       when r.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.long_deg||' '||fb.long_min||fb.long_sec,1,15),
        substr(r.long_deg||' '||r.long_min||r.long_sec,1,15)
      )    "REL LONG",
count(c.tag_no1),
c.block "RECAP BLOCK",
decode(
       case when c.lat_deg is null then 'NULL'
       when c.lat_min is null then 'NULL'
       when c.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.lat_deg||' '||fb2.lat_min||fb2.lat_sec,1,15),
        substr(c.lat_deg||' '||c.lat_min||c.lat_sec,1,15)
      )    "RECAP LAT",
decode(
       case when c.long_deg is null then 'NULL'
       when c.long_min is null then 'NULL'
       when c.long_sec is null then 'NULL' else 'OK' end,
```

```
       'NULL', substr(fb2.long_deg||' '||fb2.long_min||fb2.long_sec,1,15),
        substr(c.long_deg||' '||c.long_min||c.long_sec,1,15)
      )    "RECAP LONG"
from pt_release2 r, pt_recapture1 c, pt_release1 r1, prs_fblock fb, prs_fblock fb2
where  r1.tag_no2 = c.tag_no1
and r.id = r1.id
and r.vessel = r1.vessel
and r.batch  = r1.batch
and r.rel_date = r1.rel_date
and r.block = fb.fshblk(+)
and c.block = fb2.fshblk(+)
group  by  r.rel_date,  r.batch,  r.id,    r.vessel,  r.tag_type1,  tag_start_no1,
r.tag_type2, tag_start_no2, tag_total,
drop_no,
r.area, r.region, r.block, r.station,
decode(
       case when r.lat_deg is null then 'NULL'
       when r.lat_min is null then 'NULL'
       when r.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.lat_deg||' '||fb.lat_min||fb.lat_sec,1,15),
        substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15)
      ),
decode(
       case when r.long_deg is null then 'NULL'
       when r.long_min is null then 'NULL'
       when r.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.long_deg||' '||fb.long_min||fb.long_sec,1,15),
        substr(r.long_deg||' '||r.long_min||r.long_sec,1,15)
      ),
c.block,
decode(
       case when c.lat_deg is null then 'NULL'
       when c.lat_min is null then 'NULL'
       when c.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.lat_deg||' '||fb2.lat_min||fb2.lat_sec,1,15),
        substr(c.lat_deg||' '||c.lat_min||c.lat_sec,1,15)
      ),
decode(
       case when c.long_deg is null then 'NULL'
       when c.long_min is null then 'NULL'
       when c.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.long_deg||' '||fb2.long_min||fb2.long_sec,1,15),
        substr(c.long_deg||' '||c.long_min||c.long_sec,1,15)
      )
order by 1,2,3,4;

-- Match release detail tag2 with recapture detail tag2

select   r.rel_date,   r.batch,   r.id,     r.vessel,   r.tag_type1,   tag_start_no1,
r.tag_type2, tag_start_no2, tag_total,
drop_no,
r.area, r.region, r.block, r.station,
decode(
       case when r.lat_deg is null then 'NULL'
       when r.lat_min is null then 'NULL'
       when r.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.lat_deg||' '||fb.lat_min||fb.lat_sec,1,15),
        substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15)
      )    "REL LAT",
decode(
       case when r.long_deg is null then 'NULL'
       when r.long_min is null then 'NULL'
       when r.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.long_deg||' '||fb.long_min||fb.long_sec,1,15),
        substr(r.long_deg||' '||r.long_min||r.long_sec,1,15)
      )    "REL LONG",
count(c.tag_no1),
c.block "RECAP BLOCK",
decode(
       case when c.lat_deg is null then 'NULL'
       when c.lat_min is null then 'NULL'
       when c.lat_sec is null then 'NULL' else 'OK' end,
```

```
       'NULL', substr(fb2.lat_deg||' '||fb2.lat_min||fb2.lat_sec,1,15),
        substr(c.lat_deg||' '||c.lat_min||c.lat_sec,1,15)
      )    "RECAP LAT",
decode(
       case when c.long_deg is null then 'NULL'
       when c.long_min is null then 'NULL'
       when c.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.long_deg||' '||fb2.long_min||fb2.long_sec,1,15),
        substr(c.long_deg||' '||c.long_min||c.long_sec,1,15)
      )    "RECAP LONG"
from pt_release2 r, pt_recapture1 c, pt_release1 r1, prs_fblock fb, prs_fblock fb2
where  r1.tag_no2 = c.tag_no2
and r.id = r1.id
and r.vessel = r1.vessel
and r.batch  = r1.batch
and r.rel_date = r1.rel_date
and r.block = fb.fshblk(+)
and c.block = fb2.fshblk(+)
group  by  r.rel_date,  r.batch,  r.id,    r.vessel,  r.tag_type1,  tag_start_no1,
r.tag_type2, tag_start_no2, tag_total,
drop_no,
r.area, r.region, r.block, r.station,
decode(
       case when r.lat_deg is null then 'NULL'
       when r.lat_min is null then 'NULL'
       when r.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.lat_deg||' '||fb.lat_min||fb.lat_sec,1,15),
        substr(r.lat_deg||' '||r.lat_min||r.lat_sec,1,15)
      ),
decode(
       case when r.long_deg is null then 'NULL'
       when r.long_min is null then 'NULL'
       when r.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb.long_deg||' '||fb.long_min||fb.long_sec,1,15),
        substr(r.long_deg||' '||r.long_min||r.long_sec,1,15)
      ),
c.block,
decode(
       case when c.lat_deg is null then 'NULL'
       when c.lat_min is null then 'NULL'
       when c.lat_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.lat_deg||' '||fb2.lat_min||fb2.lat_sec,1,15),
        substr(c.lat_deg||' '||c.lat_min||c.lat_sec,1,15)
      ),
decode(
       case when c.long_deg is null then 'NULL'
       when c.long_min is null then 'NULL'
       when c.long_sec is null then 'NULL' else 'OK' end,
       'NULL', substr(fb2.long_deg||' '||fb2.long_min||fb2.long_sec,1,15),
        substr(c.long_deg||' '||c.long_min||c.long_sec,1,15)
      )
order by 1,2,3,4;

spool off
```

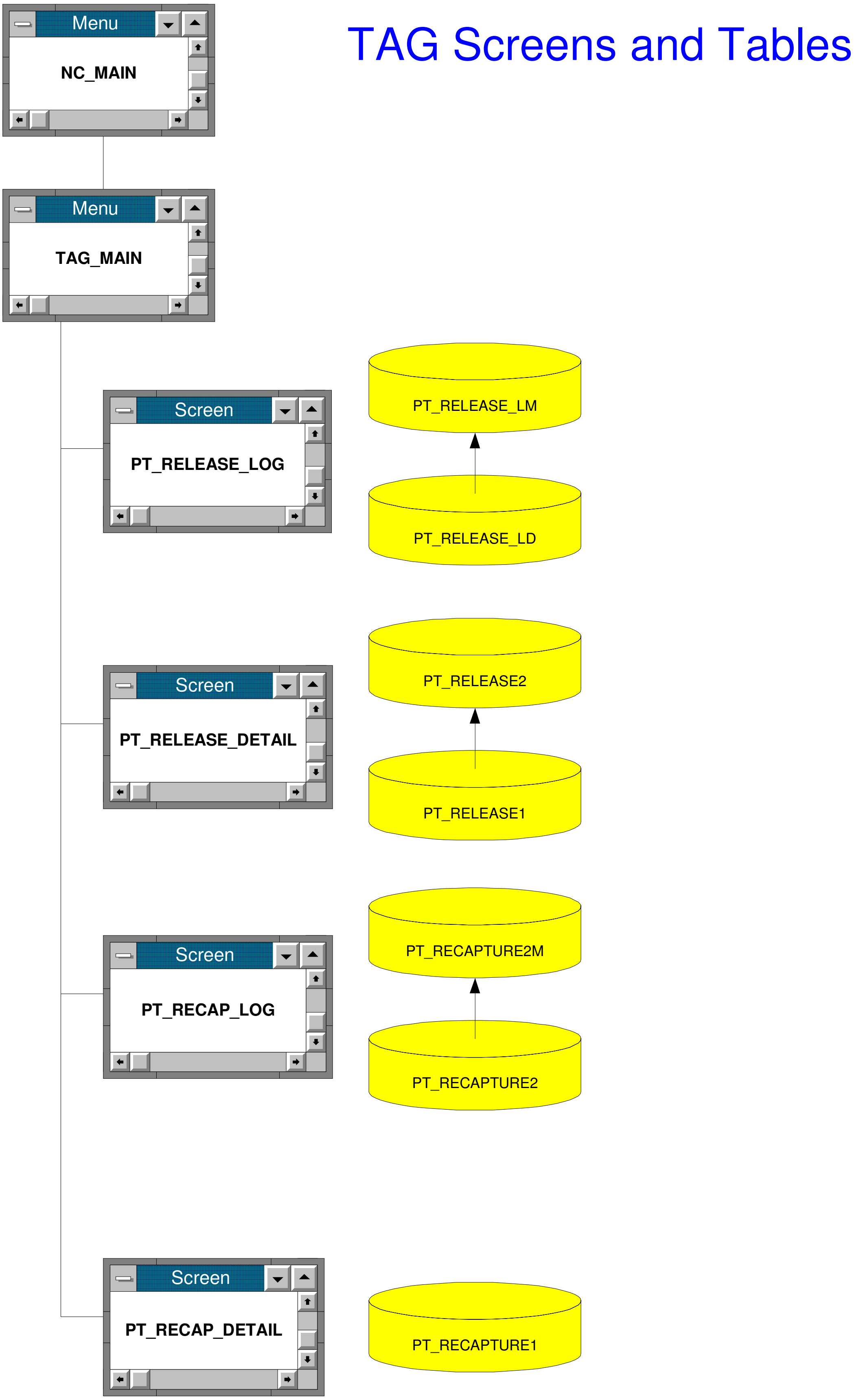
Tag_rel_vs_recap1.sql

```
rem tag_rel_vs_recap1.sql

set linesize 500
set pagesize 999

-- Add cols tag_typ1 from release and recapture at end of output row

spool tag_rel_vs_recap1.txt

select  rel1.tag_no1,  rel1.batch,  to_char(rel1.rel_date,'DD-MM-YYYY')  "REL_DATE",
rel1.block, rel1.station,
rel2.lat_deg + rel2.lat_min/60 + rel2.lat_sec/60 "LAT DEC",
```

```
rel2.long_deg + rel2.long_min/60 + rel2.long_sec/60 "LONG DEC",
rel2.lat_deg, substr(rel2.lat_min||rel2.lat_sec,1,20) "LAT_MIN",
rel2.long_deg, substr(rel2.long_min||rel2.long_sec,1,20) "LONG_MIN",
rel1.sex, rel1.tag_length,
to_char(cap1.recapture_date,'DD-MM-YYYY') "RECAP_DATE",
cap1.block "RECAP_BLOCK",
cap1.station "RECAP_STN",
cap1.lat_deg + cap1.lat_min/60 + cap1.lat_sec/60 "LAT DEC",
cap1.long_deg + cap1.long_min/60 + cap1.long_sec/60 "LONG DEC",
cap1.lat_deg, substr(cap1.lat_min||cap1.lat_sec,1,20) "LAT_MIN",
cap1.long_deg, substr(cap1.long_min||cap1.long_sec,1,20) "LONG_MIN",
cap1.sex "RECAP SEX",
cap1.p_length "RECAP LEN",
cap1.batch,
cap1.p_length - rel1.tag_length "DELTA_L",
cap1.recapture_date - rel1.rel_date "DAYS",
rel1.tag_type1 "REL TYPE", cap1.tag_type1 "RECAP TYPE"
from   pt_release2 rel2, pt_release1 rel1, pt_recapture1 cap1
where  rel1.tag_no1   = cap1.tag_no1
and    rel1.tag_type1 = cap1.tag_type1
and    rel1.id = rel2.id
--
UNION
--
select  rel1.tag_no1,  rel1.batch,  to_char(rel1.rel_date,'DD-MM-YYYY')  "REL_DATE",
rel1.block, rel1.station,
rel2.lat_deg + rel2.lat_min/60 + rel2.lat_sec/60 "LAT DEC",
rel2.long_deg + rel2.long_min/60 + rel2.long_sec/60 "LAT DEC",
rel2.lat_deg, substr(rel2.lat_min||rel2.lat_sec,1,20) "LAT_MIN",
rel2.long_deg, substr(rel2.long_min||rel2.long_sec,1,20) "LONG_MIN",
rel1.sex, rel1.tag_length,
to_char(cap1.recapture_date,'DD-MM-YYYY') "RECAP_DATE",
cap1.block "RECAP_BLOCK",
cap1.station "RECAP_STN",
cap1.lat_deg + cap1.lat_min/60 + cap1.lat_sec/60 "LAT DEC",
cap1.long_deg + cap1.long_min/60 + cap1.long_sec/60 "LONG DEC",
cap1.lat_deg, substr(cap1.lat_min||cap1.lat_sec,1,20) "LAT_MIN",
cap1.long_deg, substr(cap1.long_min||cap1.long_sec,1,20) "LONG_MIN",
cap1.sex "RECAP SEX",
cap1.p_length "RECAP LEN",
cap1.batch,
cap1.p_length - rel1.tag_length "DELTA_L",
cap1.recapture_date - rel1.rel_date "DAYS",
rel1.tag_type1 "REL TYPE", cap1.tag_type1 "RECAP TYPE"
from   pt_release2 rel2, pt_release1 rel1, pt_recapture1 cap1
where  rel1.tag_no1   = cap1.tag_no2
and    rel1.tag_type1 = cap1.tag_type2
and    rel1.id = rel2.id
--
UNION
--
select  rel1.tag_no2,  rel1.batch,  to_char(rel1.rel_date,'DD-MM-YYYY')  "REL_DATE",
rel1.block, rel1.station,
rel2.lat_deg + rel2.lat_min/60 + rel2.lat_sec/60 "LAT DEC",
rel2.long_deg + rel2.long_min/60 + rel2.long_sec/60 "LAT DEC",
rel2.lat_deg, substr(rel2.lat_min||rel2.lat_sec,1,20) "LAT_MIN",
rel2.long_deg, substr(rel2.long_min||rel2.long_sec,1,20) "LONG_MIN",
rel1.sex, rel1.tag_length,
to_char(cap1.recapture_date,'DD-MM-YYYY') "RECAP_DATE",
cap1.block "RECAP_BLOCK",
cap1.station "RECAP_STN",
cap1.lat_deg + cap1.lat_min/60 + cap1.lat_sec/60 "LAT DEC",
cap1.long_deg + cap1.long_min/60 + cap1.long_sec/60 "LONG DEC",
cap1.lat_deg, substr(cap1.lat_min||cap1.lat_sec,1,20) "LAT_MIN",
cap1.long_deg, substr(cap1.long_min||cap1.long_sec,1,20) "LONG_MIN",
cap1.sex "RECAP SEX",
cap1.p_length "RECAP LEN",
cap1.batch,
cap1.p_length - rel1.tag_length "DELTA_L",
cap1.recapture_date - rel1.rel_date "DAYS",
rel1.tag_type1 "REL TYPE", cap1.tag_type1 "RECAP TYPE"
from   pt_release2 rel2, pt_release1 rel1, pt_recapture1 cap1
```

```
where  rel1.tag_no2   = cap1.tag_no1
and    rel1.tag_type2 = cap1.tag_type1
and    rel1.id = rel2.id
--
UNION
--
select  rel1.tag_no2,  rel1.batch,  to_char(rel1.rel_date,'DD-MM-YYYY')  "REL_DATE",
rel1.block, rel1.station,
rel2.lat_deg + rel2.lat_min/60 + rel2.lat_sec/60 "LAT DEC",
rel2.long_deg + rel2.long_min/60 + rel2.long_sec/60 "LAT DEC",
rel2.lat_deg, substr(rel2.lat_min||rel2.lat_sec,1,20) "LAT_MIN",
rel2.long_deg, substr(rel2.long_min||rel2.long_sec,1,20) "LONG_MIN",
rel1.sex, rel1.tag_length,
to_char(cap1.recapture_date,'DD-MM-YYYY') "RECAP_DATE",
cap1.block "RECAP_BLOCK",
cap1.station "RECAP_STN",
cap1.lat_deg + cap1.lat_min/60 + cap1.lat_sec/60 "LAT DEC",
cap1.long_deg + cap1.long_min/60 + cap1.long_sec/60 "LONG DEC",
cap1.lat_deg, substr(cap1.lat_min||cap1.lat_sec,1,20) "LAT_MIN",
cap1.long_deg, substr(cap1.long_min||cap1.long_sec,1,20) "LONG_MIN",
cap1.sex "RECAP SEX",
cap1.p_length "RECAP LEN",
cap1.batch,
cap1.p_length - rel1.tag_length "DELTA_L",
cap1.recapture_date - rel1.rel_date "DAYS",
rel1.tag_type1 "REL TYPE", cap1.tag_type1 "RECAP TYPE"
from   pt_release2 rel2, pt_release1 rel1, pt_recapture1 cap1
where  rel1.tag_no2   = cap1.tag_no2
and    rel1.tag_type2 = cap1.tag_type2
and    rel1.id = rel2.id
order by 1;


spool off
```

TAG data map



TAG Screens and Tables
Menu
NC_MAIN
Menu
TAG_MAIN
Screen
PT_RELEASE_LOG
PT_RELEASE_LM
PT_RELEASE_LD
Screen
PT_RELEASE_DETAIL
PT_RELEASE2
PT_RELEASE1
Screen
PT_RECAP_LOG
PT_RECAPTURE2M
PT_RECAPTURE2
Screen
PT_RECAP_DETAIL
PT_RECAPTURE1

TAG TABLES

PT_CODE
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 CODE_GROUP                             VARCHAR2(15)
 CODE_SUBGROUP                          VARCHAR2(15)
 CODE                                   VARCHAR2(15)
 CODE_TEXT                              VARCHAR2(50)
 CODE_TEXT_LONG                         VARCHAR2(200)
 CODE_STATUS                            VARCHAR2(15)
 CODE2                                  VARCHAR2(30)
 CODE3                                  VARCHAR2(30)
```

PT_FISHING_PERIODS
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 PERIOD                                 VARCHAR2(15)
 START_DATE                    NOT NULL DATE
 END_DATE                               DATE
```

PT_LOAD1
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LOADSEQ                                VARCHAR2(15)
 GROUP_NO                               NUMBER
 BATCH                                  VARCHAR2(15)
 VESSEL                                 VARCHAR2(15)
 REL_DATE                               VARCHAR2(15)
 STATION                                VARCHAR2(15)
 BLOCK                                  VARCHAR2(15)
 LATITUDE                               VARCHAR2(15)
 LONGITUDE                              VARCHAR2(15)
 TAG_DROP                               VARCHAR2(15)
 TAGGER                                 VARCHAR2(15)
 MEASURER                               VARCHAR2(15)
 RECORDER                               VARCHAR2(15)
 TAG_TYPE                               VARCHAR2(15)
 TAG_TYPE2                              VARCHAR2(15)
 TAG_TYPE3                              VARCHAR2(15)
 TAG_FROM                               VARCHAR2(15)
 TAG_FROM2                              VARCHAR2(15)
 TAG_FROM3                              VARCHAR2(15)
 TAG_TO                                 VARCHAR2(15)
 TAG_TO2                                VARCHAR2(15)
 TAG_NO1S                               VARCHAR2(15)
 TAG_NO2S                               VARCHAR2(15)
 TAG_NO                                 VARCHAR2(15)
 SEX                                    VARCHAR2(15)
 BIGNO                                  VARCHAR2(15)
 LENGTH                                 VARCHAR2(15)
 TP                                     VARCHAR2(15)
 TAG_DROP2                              VARCHAR2(15)
 RELCK                                  VARCHAR2(15)
 MEASURED                               VARCHAR2(15)
 TAG_NO2                                VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(100)
```

PT_LOAD1_COMMENT
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 GROUP_NO                               NUMBER
 VESSEL                                 VARCHAR2(15)
 REL_DATE                               VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(200)
 SEQ                                    NUMBER(38)
 LOADSEQ                                VARCHAR2(15)
```

PT_LOAD2
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LOADSEQ                                VARCHAR2(15)
 GROUP_NO                               NUMBER
 BATCH                                  VARCHAR2(15)
 VESSEL                                 VARCHAR2(15)
 REL_DATE                               VARCHAR2(15)
 STATION                                VARCHAR2(15)
 BLOCK                                  VARCHAR2(15)
 LATITUDE                               VARCHAR2(15)
 LONGITUDE                              VARCHAR2(15)
 TAG_DROP                               VARCHAR2(15)
 TAGGER                                 VARCHAR2(15)
 MEASURER                               VARCHAR2(15)
 RECORDER                               VARCHAR2(15)
 TAG_TYPE                               VARCHAR2(15)
 TAG_TYPE2                              VARCHAR2(15)
 TAG_TYPE3                              VARCHAR2(15)
 TAG_FROM                               VARCHAR2(15)
 TAG_FROM2                              VARCHAR2(15)
 TAG_FROM3                              VARCHAR2(15)
 TAG_TO                                 VARCHAR2(15)
 TAG_TO2                                VARCHAR2(15)
 TAG_NO1S                               VARCHAR2(15)
 TAG_NO2S                               VARCHAR2(15)
 TAG_NO                                 VARCHAR2(15)
 SEX                                    VARCHAR2(15)
 BIGNO                                  VARCHAR2(15)
 LENGTH                                 VARCHAR2(15)
 TP                                     VARCHAR2(15)
 TAG_DROP2                              VARCHAR2(15)
 RELCK                                  VARCHAR2(15)
 MEASURED                               VARCHAR2(15)
 TAG_NO2                                VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(100)
```

PT_LOAD2_COMMENT
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 GROUP_NO                               NUMBER
 VESSEL                                 VARCHAR2(15)
 REL_DATE                               VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(200)
 SEQ                                    NUMBER(38)
 LOADSEQ                                VARCHAR2(15)
```

PT_LOAD3
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LOADSEQ                                VARCHAR2(15)
 GROUP_NO                               NUMBER
 BATCH                                  VARCHAR2(15)
 VESSEL                                 VARCHAR2(15)
 REL_DATE                               VARCHAR2(15)
 STATION                                VARCHAR2(15)
 BLOCK                                  VARCHAR2(15)
 LATITUDE                               VARCHAR2(15)
 LONGITUDE                              VARCHAR2(15)
 TAG_DROP                               VARCHAR2(15)
 TAGGER                                 VARCHAR2(15)
 MEASURER                               VARCHAR2(15)
 TAG_TYPE                               VARCHAR2(15)
 TAG_TYPE2                              VARCHAR2(15)
 TAG_TYPE3                              VARCHAR2(15)
 TAG_FROM                               VARCHAR2(15)
 TAG_FROM2                              VARCHAR2(15)
 TAG_FROM3                              VARCHAR2(15)
 TAG_TO                                 VARCHAR2(15)
 TAG_TO2                                VARCHAR2(15)
 TAG_NO1S                               VARCHAR2(15)
 TAG_NO2S                               VARCHAR2(15)
 RECORDER                               VARCHAR2(15)
 TAG_NO                                 VARCHAR2(15)
 SEX                                    VARCHAR2(15)
 BIGNO                                  VARCHAR2(15)
 LENGTH                                 VARCHAR2(15)
 TP                                     VARCHAR2(15)
 TAG_DROP2                              VARCHAR2(15)
 RELCK                                  VARCHAR2(15)
 MEASURED                               VARCHAR2(15)
 TAG_NO2                                VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(100)
```

PT_LOAD3_COMMENT
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 GROUP_NO                               NUMBER
 VESSEL                                 VARCHAR2(15)
 REL_DATE                               VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(200)
 SEQ                                    NUMBER(38)
 LOADSEQ                                VARCHAR2(15)
```

PT_LOAD_EXCEL1
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LOADSEQ                                NUMBER
 COL1                                   VARCHAR2(50)
 COL2                                   VARCHAR2(50)
 COL3                                   VARCHAR2(50)
 COL4                                   VARCHAR2(50)
 COL5                                   VARCHAR2(50)
 COL6                                   VARCHAR2(50)
 COL7                                   VARCHAR2(50)
 COL8                                   VARCHAR2(50)
 COL9                                   VARCHAR2(50)
 COL10                                  VARCHAR2(50)
 COL11                                  VARCHAR2(100)
```

PT_LOAD_EXCEL2
```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LOADSEQ                                NUMBER
 COL1                                   VARCHAR2(50)
 COL2                                   VARCHAR2(50)
 COL3                                   VARCHAR2(50)
 COL4                                   VARCHAR2(50)
 COL5                                   VARCHAR2(50)
 COL6                                   VARCHAR2(50)
 COL7                                   VARCHAR2(50)
 COL8                                   VARCHAR2(50)
```

```
 COL9                                   VARCHAR2(50)
 COL10                                  VARCHAR2(50)
 COL11                                  VARCHAR2(100)
```

PT_LOAD_EXCEL3

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LOADSEQ                                NUMBER
 COL1                                   VARCHAR2(50)
 COL2                                   VARCHAR2(50)
 COL3                                   VARCHAR2(50)
 COL4                                   VARCHAR2(50)
 COL5                                   VARCHAR2(50)
 COL6                                   VARCHAR2(50)
 COL7                                   VARCHAR2(50)
 COL8                                   VARCHAR2(50)
 COL9                                   VARCHAR2(50)
 COL10                                  VARCHAR2(50)
 COL11                                  VARCHAR2(100)
```

PT_LOG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 TAG_DATE                               DATE
 SHOTNO                                 NUMBER
 BLOCK                                  VARCHAR2(15)
 RADAR                                  VARCHAR2(15)
 TAG_NO                                 VARCHAR2(15)
 TAG_TOTAL                              NUMBER
```

PT_RECAPTURE1

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 SOURCE                                 VARCHAR2(15)
 AREA                                   VARCHAR2(3)
 REGION                                 VARCHAR2(6)
 VESSEL                        NOT NULL VARCHAR2(15)
 RECAPTURE_DATE                NOT NULL DATE
 TAG_NO1                       NOT NULL VARCHAR2(15)
 TAG_NO2                                VARCHAR2(15)
 SEX                                    VARCHAR2(2)
 P_LENGTH                               NUMBER
 BLOCK                                  VARCHAR2(15)
 GRID                                   VARCHAR2(15)
 DEPTH                                  NUMBER
 HEAD_ON                                VARCHAR2(1)
 COOKED                                 VARCHAR2(1)
 HARD_SOFT                              VARCHAR2(1)
 LAT_DEG                                NUMBER
 LAT_MIN                                NUMBER
 LAT_SEC                                NUMBER
 LONG_DEG                               NUMBER
 LONG_MIN                               NUMBER
 LONG_SEC                               NUMBER
 LAT_SEC_ALPHA                          VARCHAR2(3)
 LONG_SEC_ALPHA                         VARCHAR2(3)
 RADAR                                  VARCHAR2(200)
 STATION                                VARCHAR2(5)
 TAG_TYPE1                     NOT NULL VARCHAR2(15)
 TAG_TYPE2                              VARCHAR2(15)
 TAG_COUNT                              NUMBER(38)
 TAG_POSITION1                          VARCHAR2(15)
 TAG_POSITION2                          VARCHAR2(15)
 CHEWED                                 VARCHAR2(15)
 MEASURE_DATE                           DATE
 MEASURER1                              VARCHAR2(15)
 MEASURER2                              VARCHAR2(15)
 MEASURER3                              VARCHAR2(15)
 PROBLEM_CODE                           VARCHAR2(15)
 RELIAB_CODE                            VARCHAR2(15)
 RECAP_COMMENT                          VARCHAR2(2000)
 BATCH                                  NUMBER(38)
```

PT_RECAPTURE2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 VESSEL                        NOT NULL VARCHAR2(15)
 START_DATE                    NOT NULL DATE
 RECAPTURE_DATE                NOT NULL DATE
 SHOT_NO                                NUMBER(38)
 AREA                                   VARCHAR2(3)
 REGION                                 VARCHAR2(6)
 FSHBLK                        NOT NULL VARCHAR2(6)
 STATION                                VARCHAR2(5)
 RADAR                                  VARCHAR2(100)
 GPS_LAT_DEG                            NUMBER
 GPS_LAT_MIN                            NUMBER
 GPS_LAT_SEC                            NUMBER
 GPS_LONG_DEG                           NUMBER
 GPS_LONG_MIN                           NUMBER
 GPS_LONG_SEC                           NUMBER
 GPS_LAT_SEC_ALPHA                      VARCHAR2(3)
 GPS_LONG_SEC_ALPHA                     VARCHAR2(3)
 DEPTH                                  NUMBER
 TAG_NO                        NOT NULL VARCHAR2(20)
 TAG_SINGLE                             VARCHAR2(15)
 PROBLEM_CODE                           VARCHAR2(15)
 RELIAB_CODE                            VARCHAR2(15)
```

PT_RECAPTURE2M

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 VESSEL                        NOT NULL VARCHAR2(15)
 VESSEL_LICENCE_NO                      VARCHAR2(15)
 SKIPPER                                VARCHAR2(15)
 START_DATE                    NOT NULL DATE
 CREW1                                  VARCHAR2(15)
 CREW2                                  VARCHAR2(15)
 CREW3                                  VARCHAR2(15)
 CREW4                                  VARCHAR2(15)
 CREW5                                  VARCHAR2(15)
 BATCH                                  NUMBER(38)
```

PT_RELEASE1

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 VESSEL                        NOT NULL VARCHAR2(15)
 REL_DATE                      NOT NULL DATE
 ID                            NOT NULL NUMBER(38)
 AREA                                   VARCHAR2(3)
 REGION                                 VARCHAR2(6)
 BLOCK                                  VARCHAR2(15)
 STATION                                VARCHAR2(15)
 BATCH                                  NUMBER(38)
 TAG_TYPE1                              VARCHAR2(10)
 TAG_TYPE2                              VARCHAR2(10)
 TAG_NO1                       NOT NULL VARCHAR2(15)
 TAG_NO2                                VARCHAR2(15)
 SEX                                    VARCHAR2(2)
 TAG_LENGTH                             NUMBER
 RELCK                                  VARCHAR2(15)
 TAGGER                                 VARCHAR2(15)
 MEASURER                               VARCHAR2(15)
 PROBLEM_CODE                           VARCHAR2(15)
 RELIAB_CODE                            VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(100)
```

PT_RELEASE1_TEMP

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 GROUP_NO                      NOT NULL NUMBER
 REL_DATE_EXCEL                         VARCHAR2(15)
 REL_DATE                               DATE
 VESSEL                        NOT NULL VARCHAR2(15)
 BLOCK                         NOT NULL VARCHAR2(15)
 STATION                       NOT NULL VARCHAR2(15)
 TAG_NO                        NOT NULL VARCHAR2(15)
 SEX                                    VARCHAR2(2)
 LENGTH_CHAR                            VARCHAR2(15)
 LENGTH                                 NUMBER
 RELCK                                  VARCHAR2(15)
 MEASURED                               VARCHAR2(15)
 PROBLEM_CODE4                          VARCHAR2(15)
 PROBLEM_CODE5                          VARCHAR2(15)
 PROBLEM_CODE6                          VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(100)
```

PT_RELEASE2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 VESSEL                        NOT NULL VARCHAR2(15)
 REL_DATE                      NOT NULL DATE
 ID                            NOT NULL NUMBER(38)
 AREA                                   VARCHAR2(3)
 REGION                                 VARCHAR2(6)
 BLOCK                                  VARCHAR2(15)
 STATION                                VARCHAR2(15)
 BATCH                                  NUMBER(38)
 GRID                                   VARCHAR2(4)
 DEPTH                                  NUMBER
 LAT_DEG                                NUMBER
 LAT_MIN                                NUMBER
 LAT_SEC                                NUMBER
 LONG_DEG                               NUMBER
 LONG_MIN                               NUMBER
 LONG_SEC                               NUMBER
 LAT_SEC_ALPHA                          VARCHAR2(3)
 LONG_SEC_ALPHA                         VARCHAR2(3)
 DROP_NO                                NUMBER
 TAG_TYPE1                              VARCHAR2(10)
 TAG_TYPE2                              VARCHAR2(10)
 TAG_START_NO1                          VARCHAR2(15)
 TAG_START_NO2                          VARCHAR2(15)
 TAG_END_NO1                            VARCHAR2(15)
 TAG_END_NO2                            VARCHAR2(15)
 TAG_POSITION1                          VARCHAR2(15)
 TAG_POSITION2                          VARCHAR2(15)
 TAG_TOTAL                              NUMBER
 RELEASE_SUCCESS                        VARCHAR2(3)
 MEASURED                               VARCHAR2(15)
 PROBLEM_CODE                           VARCHAR2(15)
 RELIAB_CODE                            VARCHAR2(15)
 TAG_COMMENT                            VARCHAR2(4000)
```

PT_RELEASE2_TEMP

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 GROUP_NO                      NOT NULL NUMBER
 REL_DATE_EXCEL                         VARCHAR2(15)
 REL_DATE                               DATE
 VESSEL                        NOT NULL VARCHAR2(15)
 BLOCK                         NOT NULL VARCHAR2(15)
 STATION                       NOT NULL VARCHAR2(15)
 TAG_TYPE                               VARCHAR2(10)
 TAG_TYPE2                              VARCHAR2(10)
```

```
 TAG_TYPE3                                VARCHAR2(10)
 TAG_FROM1                                VARCHAR2(15)
 TAG_TO1                                  VARCHAR2(15)
 TAG_FROM2                                VARCHAR2(15)
 TAG_TO2                                  VARCHAR2(15)
 TAG_FROM3                                VARCHAR2(15)
 TAG_NO1S                                 VARCHAR2(15)
 TAG_NO2S                                 VARCHAR2(15)
 TAG_POSITION                             VARCHAR2(15)
 MEASURED_YN                              VARCHAR2(15)
 TAGGER                                   VARCHAR2(15)
 MEASURER                                 VARCHAR2(15)
 DEPTH                                    NUMBER
 PROBLEM_CODE1                            VARCHAR2(15)
 PROBLEM_CODE2                            VARCHAR2(15)
 PROBLEM_CODE3                            VARCHAR2(15)
```

PT_RELEASELD

```
 Name                            Null?    Type
 ------------------------------- -------- ------------------
--
 VESSEL                          NOT NULL VARCHAR2(15)
 LOG_DATE                        NOT NULL DATE
 AREA                            NOT NULL VARCHAR2(3)
 REGION                          NOT NULL VARCHAR2(6)
 BLOCK                                    VARCHAR2(15)
 STATION                         NOT NULL VARCHAR2(15)
 TAG_TYPE                        NOT NULL VARCHAR2(10)
 TAG_NO_START                    NOT NULL VARCHAR2(15)
 TAG_NO_END                               VARCHAR2(15)
 TAG_POSITION                             VARCHAR2(15)
 TAG_TOTAL                                NUMBER(38)
 DEPTH                                    NUMBER
 RADAR                                    VARCHAR2(200)
 LOG_COMMENT                              VARCHAR2(200)
```

PT_RELEASELM

```
 Name                            Null?    Type
 ------------------------------- -------- -------------------
-
 VESSEL                          NOT NULL VARCHAR2(15)
 LOG_DATE                                 NOT  NULL  DATE
```

TAG TABLE INDEXES

TABLE_NAME	***C***	***CONSTRAINT_NAME***	***col_name***	***STATUS***
PT_FISHING_PERIODS	P	SYS_C0015332	START_DATE	ENABLED
PT_RECAPTURE1	P	SYS_C0015366	RECAPTURE_DATE	ENABLED
			TAG_NO1	ENABLED
			TAG_TYPE1	ENABLED
			VESSEL	ENABLED
PT_RECAPTURE2	P	SYS_C0015364	FSHBLK	ENABLED
			RECAPTURE_DATE	ENABLED
			START_DATE	ENABLED
			TAG_NO	ENABLED
			VESSEL	ENABLED
	R	SYS_C0015365	START_DATE	ENABLED
			VESSEL	ENABLED
PT_RECAPTURE2M	P	SYS_C0015330	START_DATE	ENABLED
			VESSEL	ENABLED
PT_RELEASE1	P	SYS_C0015358	ID	ENABLED
			REL_DATE	ENABLED
			TAG_NO1	ENABLED
			VESSEL	ENABLED
	R	SYS_C0015357	ID	ENABLED
			REL_DATE	ENABLED
			VESSEL	ENABLED
PT_RELEASE1_TEMP	P	SYS_C0015328	BLOCK	ENABLED
			GROUP_NO	ENABLED
			STATION	ENABLED
			TAG_NO	ENABLED
			VESSEL	ENABLED

	R	SYS_C0015329	BLOCK	ENABLED
			GROUP_NO	ENABLED
			STATION	ENABLED
			VESSEL	ENABLED
PT_RELEASE2	P	SYS_C0015355	ID	ENABLED
			REL_DATE	ENABLED
			VESSEL	ENABLED
PT_RELEASE2_TEMP	P	SYS_C0015327	BLOCK	ENABLED
			GROUP_NO	ENABLED
			STATION	ENABLED
			VESSEL	ENABLED
PT_RELEASELD	P	SYS_C0015368	AREA	ENABLED
			LOG_DATE	ENABLED
			REGION	ENABLED
			STATION	ENABLED
			TAG_NO_START	ENABLED
			TAG_TYPE	ENABLED
			VESSEL	ENABLED
	R	SYS_C0015369	LOG_DATE	ENABLED
			VESSEL	ENABLED
PT_RELEASELM	P	SYS_C0015367	LOG_DATE	ENABLED
			VESSEL	ENABLED

Catch Monitoring System (CMS) database

Catch Monitoring System (sometimes known as Catch Effort) records commercial prawn trawling results. This data is then used to support analysis of prawn stock and harvest levels.

CMS Main Menu

Screen Title	Purpose	Form name
Fishing Periods	Fishing Periods	ce_fp
Vessels	Vessels	ce_vessels
Vessels (old)	Vessels (old)	?
Commercial Grades	Commercial Grades	ce_grade
Commercial Prices	Commercial Prices	ce_price
Landing Logbook A1	Landing Logbook A1	ce_land_log
Daily Log (A9 & A5)	Daily Log (A9 & A5)	ce_daily_log
Vessel Equipment (current)	Vessel Equipment (current)	ce_vessel_equip
Vessel Equipment (87/88 – 2002)	Vessel Equipment (87/88 – 2002)	ce_vessel_equip_old
Vessel calculations	Vessel calculations	ce_vessel_calc
Prawn daily and Monthly Logbook Statistics (1978) A4	Prawn daily and Monthly Logbook Statistics (1978) A4	ce_daily_log_a4
Daily Log Shot Sheet (No Tide/Trawled) A7 runs A8	Daily Log Shot Sheet (No Tide/Trawled) A7 runs A8	ce_ daily_log_a8
Prawn Daily Logbook Statistics (1978) A3	Prawn Daily Logbook Statistics (1978) A3	ce_ land_log_a3
Prawn Unloading Record Sheet A6	Prawn Unloading Record Sheet A6	ce_ land_log_a6
Record Sheet (Daily & Monthly)	Record Sheet (Daily & Monthly)	ce_record
Commercial Catch Data	Commercial Catch Data	ce_com
Commercial Buckets	Commercial Buckets	ce_com_bkt
Frequency Distribution	Frequency Distribution	ce_com_freq
Commercial Grades	Commercial Grades	ce_grade
Commercial Grade Groups	Commercial Grade Groups	ce_com_grade_group
dBase data	dBase data	ce_orig_dbase_data
Bad data from dBase	Bad data from dBase	ce_ba_dbase_data
Dataflex Com data	Dataflex Com data	ce_load_prcom_dataflex
Load SARDI data	Load SARDI data	ce_sardi_load
View SARDI Daily Log data	View SARDI Daily Log data	ce_sardi_daily
View SARDI Landing Logbook data	View SARDI Landing Logbook data	ce_sardi_land
Closures	Closures	ce_closure

Understanding the data

The Catch Management System (sometimes known as Catch Effort) collects data about commercial prawn trawling catches, price history and vessel attributes all of which can be used in the calculation of catch effort data.

There are quite a few data entry screens reflecting the diversity of this data capture. Paper forms used to record catch logs have varied over time and so this also requires a number of similar but different entry screens.

CMS Data Tables

CE_AUDIT_IMPORT
CE_CATCH_SHOT
CE_CATCH_SHOT_BKP
CE_CATCH_SUM
CE_CATCH_SUM2
CE_CATCH_SUM2_BKP
CE_CATCH_SUM_BKP
CE_CODES
CE_COM
CE_COM_BKT
CE_COM_BKT_DETAIL
CE_COM_DETAIL
CE_COM_GRADE_GROUP
CE_FP
CE_FP_DAYS
CE_GRADE
CE_GRADE_SHOT
CE_IMP_LAND_DETAIL
CE_IMP_LAND_LOG
CE_IMP_SHOT
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CE_LAND_DETAIL
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CE_LAND_LOG
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CE_PRICE
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CE_SHOT_A8
CE_SHOT_LOG
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CE_SHOT_LOG_DETAIL
CE_TAG_A8
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CE_TMP_DUP_SHOT
CE_TMP_SHOT_DELETED
CE_VESSEL
CE_VESSEL_CALC
CE_VESSEL_EQUIP
CE_VESSEL_EQUIP_OLD
CE_VESSEL_PRE_FP
CLOSURE
CLOSURE_DETAIL

Table structure

CE_AUDIT_IMPORT

```
Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 ID                            NOT NULL NUMBER(38)
 DAY                                    DATE
 ACTION                                 VARCHAR2(30)
 NOTE                                   VARCHAR2(500)
 STATUS                                 VARCHAR2(30)
```

CE_CATCH_SHOT

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              DATE
 TO_DATE                                DATE
 DAY                           NOT NULL DATE
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 SHOT                          NOT NULL NUMBER(38)
 BLOCK_NO                      NOT NULL VARCHAR2(10)
 START_TIME                             VARCHAR2(10)
 DURATION                               NUMBER
 CATCH_KG_ACTUAL                        NUMBER
 CATCH_KG_EXPECT                        NUMBER
 ADJUST                                 NUMBER
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
```

CE_CATCH_SUM

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              DATE
 TO_DATE                                DATE
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 DAY                           NOT NULL DATE
 CARTONS                                NUMBER
 QUANT_KG                               NUMBER
 GREEN_KG                               NUMBER
 COOKED_KG                              NUMBER
 LANDING_NO                    NOT NULL NUMBER(38)
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
```

CE_CATCH_SUM2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              DATE
 TO_DATE                                DATE
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 CARTONS                                NUMBER
 QUANT_KG                               NUMBER
 GREEN_KG                               NUMBER
 COOKED_KG                              NUMBER
 SHOT_KG                                NUMBER
 ADJUST                                 NUMBER
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
```

CE_CODES

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 CODE_USE                      NOT NULL VARCHAR2(50)
 CODE                          NOT NULL VARCHAR2(20)
 CODE_NAME                              VARCHAR2(100)
 CODE_GROUP                    NOT NULL VARCHAR2(100)
 CODE_COL2                              VARCHAR2(100)
 START_DATE                             DATE
 END_DATE                               DATE
 STATUS                                 VARCHAR2(10)
 ORDER_NO                               NUMBER(38)
 NOTE                                   VARCHAR2(100)
```

CE_COM

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 FP                            NOT NULL VARCHAR2(20)
 SKIPPER                                VARCHAR2(30)
 CARTON_WEIGHT1                         NUMBER
 CARTON_WEIGHT2                         NUMBER
```

```
 CARTON_WEIGHT3                          NUMBER
 GRADE1                                  VARCHAR2(30)
 GRADE2                                  VARCHAR2(30)
 GRADE3                                  VARCHAR2(30)
 GRADE4                                  VARCHAR2(30)
 GRADE5                                  VARCHAR2(30)
 GRADE6                                  VARCHAR2(30)
 GRADE7                                  VARCHAR2(30)
 GRADE8                                  VARCHAR2(30)
 GRADE9                                  VARCHAR2(30)
 CTN_KG_FLAG                             VARCHAR2(30)
 SOURCE                                  VARCHAR2(50)
 NOTE                                    VARCHAR2(200)
 WT1                                     NUMBER
 WT2                                     NUMBER
 WT3                                     NUMBER
 WT4                                     NUMBER
 WT5                                     NUMBER
 WT6                                     NUMBER
 WT7                                     NUMBER
 WT8                                     NUMBER
 WT9                                     NUMBER
 TOTAL_KG1                               NUMBER
 TOTAL_KG2                               NUMBER
 TOTAL_KG3                               NUMBER
 TOTAL_KG4                               NUMBER
 TOTAL_KG5                               NUMBER
 TOTAL_KG6                               NUMBER
 TOTAL_KG7                               NUMBER
 TOTAL_KG8                               NUMBER
 TOTAL_KG9                               NUMBER
 TOTAL_KG                                NUMBER
```

CE_COM_BKT

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 VESSEL_NAME                             VARCHAR2(30)
 FP                             NOT NULL VARCHAR2(20)
 NOTE                                    VARCHAR2(100)
 SOURCE                                  VARCHAR2(50)
```

CE_COM_BKT_DETAIL

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 FP                             NOT NULL VARCHAR2(20)
 DAY                            NOT NULL DATE
 REGION                                  VARCHAR2(30)
 BLOCK                                   VARCHAR2(10)
 BUCKET_NO                      NOT NULL NUMBER(38)
 SHOT                           NOT NULL NUMBER(38)
 MALES_NO                                NUMBER
 MALES_WT                                NUMBER
 FEMALES_NO                              NUMBER
 FEMALES_WT                              NUMBER
 TOTAL_NO                                NUMBER
 TOTAL_WT                                NUMBER
 PERSONNEL                               VARCHAR2(50)
 NOTE                                    VARCHAR2(100)
 DATA_ENTRY_ORDER                        NUMBER(38)
```

CE_COM_DETAIL

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 AREA                                    VARCHAR2(1)
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 FP                             NOT NULL VARCHAR2(20)
 DAY                            NOT NULL DATE
 BLOCK1                                  VARCHAR2(10)
 BLOCK2                                  VARCHAR2(10)
 BLOCK3                                  VARCHAR2(10)
 BLOCK4                                  VARCHAR2(10)
 NO_BKT                                  NUMBER
 KG                                      NUMBER
 NO_BKT_FEMALE                           NUMBER
 KG_FEMALE                               NUMBER
 GRADE1                                  NUMBER
 GRADE2                                  NUMBER
 GRADE3                                  NUMBER
 GRADE4                                  NUMBER
 GRADE5                                  NUMBER
 GRADE6                                  NUMBER
 GRADE7                                  NUMBER
 GRADE8                                  NUMBER
 GRADE9                                  NUMBER
 GRADE_TOTAL                             NUMBER
 NOTE                                    VARCHAR2(100)
 NO_BKT_MALE                             NUMBER
 KG_MALE                                 NUMBER
 TOTAL_KG                                NUMBER
```

CE_COM_GRADE_GROUP

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 NAME                           NOT NULL VARCHAR2(50)
 ORDER_NO                                NUMBER(38)
 DEFAULT_GRP                             VARCHAR2(1)
 GRADE1                                  VARCHAR2(30)
 GRADE2                                  VARCHAR2(30)
 GRADE3                                  VARCHAR2(30)
 GRADE4                                  VARCHAR2(30)
 GRADE5                                  VARCHAR2(30)
 GRADE6                                  VARCHAR2(30)
 GRADE7                                  VARCHAR2(30)
 GRADE8                                  VARCHAR2(30)
 GRADE9                                  VARCHAR2(30)
 NOTE                                    VARCHAR2(100)
```

CE_FP

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 FP_NO                                   NUMBER(38)
 FP_NAME                                 VARCHAR2(30)
 FROM_DATE                               DATE
 TO_DATE                                 DATE
 YEAR                                    VARCHAR2(4)
 MTH_FROM                                VARCHAR2(3)
 MTH_TO                                  VARCHAR2(3)
 AREA                           NOT NULL VARCHAR2(1)
 FP                             NOT NULL VARCHAR2(20)
 YEAR_CALENDAR                           NUMBER(38)
 FP_TEMP                                 VARCHAR2(20)
```

CE_FP_DAYS

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 FROM_DATE                               DATE
 TO_DATE                                 DATE
 DAY                                     DATE
```

CE_GRADE

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 GRADE                                   VARCHAR2(30)
 GRADE_ALT_NAME                 NOT NULL VARCHAR2(30)
 GRADE_GROUP                             VARCHAR2(30)
 STATUS                                  VARCHAR2(20)
 FROM_DATE                               DATE
 TO_DATE                                 DATE
 ORDER_NO                                NUMBER(38)
 USUAL_WEIGHT                            NUMBER
 HI                                      NUMBER
 LO                                      NUMBER
 NOTE                                    VARCHAR2(100)
```

CE_GRADE_SHOT

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 FP                             NOT NULL VARCHAR2(10)
 DAY                            NOT NULL DATE
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 GRADE                          NOT NULL VARCHAR2(10)
 CARTON_SIZE                             NUMBER
 CARTON_NO                               NUMBER
 KG                                      NUMBER
```

CE_IMPORT_RAW1

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 ID                                      NUMBER(38)
 DAY                                     DATE
 COL1                                    VARCHAR2(100)
 COL2                                    VARCHAR2(100)
 COL3                                    VARCHAR2(100)
 COL4                                    VARCHAR2(100)
 COL5                                    VARCHAR2(100)
 COL6                                    VARCHAR2(100)
 COL7                                    VARCHAR2(100)
 COL8                                    VARCHAR2(100)
 COL9                                    VARCHAR2(100)
 COL10                                   VARCHAR2(100)
 COL11                                   VARCHAR2(100)
 COL12                                   VARCHAR2(100)
 COL13                                   VARCHAR2(100)
 COL14                                   VARCHAR2(100)
 COL15                                   VARCHAR2(100)
 COL16                                   VARCHAR2(100)
 COL17                                   VARCHAR2(100)
 COL18                                   VARCHAR2(100)
 COL19                                   VARCHAR2(100)
 COL20                                   VARCHAR2(100)
```

CE_IMPORT_RAW2

```
 Name                           Null?    Type
 ------------------------------ -------- ------------------
--
 ID                                      NUMBER(38)
 DAY                                     DATE
 COL1                                    VARCHAR2(100)
 COL2                                    VARCHAR2(100)
 COL3                                    VARCHAR2(100)
 COL4                                    VARCHAR2(100)
 COL5                                    VARCHAR2(100)
 COL6                                    VARCHAR2(100)
 COL7                                    VARCHAR2(100)
 COL8                                    VARCHAR2(100)
 COL9                                    VARCHAR2(100)
 COL10                                   VARCHAR2(100)
 COL11                                   VARCHAR2(100)
 COL12                                   VARCHAR2(100)
 COL13                                   VARCHAR2(100)
 COL14                                   VARCHAR2(100)
 COL15                                   VARCHAR2(100)
 COL16                                   VARCHAR2(100)
 COL17                                   VARCHAR2(100)
 COL18                                   VARCHAR2(100)
 COL19                                   VARCHAR2(100)
 COL20                                   VARCHAR2(100)
```

CE_IMPORT_RAW3

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 ID                                     NUMBER(38)
 DAY                                    DATE
 COL1                                   VARCHAR2(100)
 COL2                                   VARCHAR2(100)
 COL3                                   VARCHAR2(100)
 COL4                                   VARCHAR2(100)
 COL5                                   VARCHAR2(100)
 COL6                                   VARCHAR2(100)
 COL7                                   VARCHAR2(100)
 COL8                                   VARCHAR2(100)
 COL9                                   VARCHAR2(100)
 COL10                                  VARCHAR2(100)
 COL11                                  VARCHAR2(100)
 COL12                                  VARCHAR2(100)
 COL13                                  VARCHAR2(100)
 COL14                                  VARCHAR2(100)
 COL15                                  VARCHAR2(100)
 COL16                                  VARCHAR2(100)
 COL17                                  VARCHAR2(100)
 COL18                                  VARCHAR2(100)
 COL19                                  VARCHAR2(100)
 COL20                                  VARCHAR2(100)
```

CE_IMPORT_RAW4

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 ID                                     NUMBER(38)
 DAY                                    DATE
 COL1                                   VARCHAR2(100)
 COL2                                   VARCHAR2(100)
 COL3                                   VARCHAR2(100)
 COL4                                   VARCHAR2(100)
 COL5                                   VARCHAR2(100)
 COL6                                   VARCHAR2(100)
 COL7                                   VARCHAR2(100)
 COL8                                   VARCHAR2(100)
 COL9                                   VARCHAR2(100)
 COL10                                  VARCHAR2(100)
 COL11                                  VARCHAR2(100)
 COL12                                  VARCHAR2(100)
 COL13                                  VARCHAR2(100)
 COL14                                  VARCHAR2(100)
 COL15                                  VARCHAR2(100)
 COL16                                  VARCHAR2(100)
 COL17                                  VARCHAR2(100)
 COL18                                  VARCHAR2(100)
 COL19                                  VARCHAR2(100)
 COL20                                  VARCHAR2(100)
```

CE_IMP_LAND_DETAIL

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 ORDER_NO                      NOT NULL NUMBER(38)
 CARTON_NO                              NUMBER
 CARTON_WT                              NUMBER
 PRAWN_WT                               NUMBER
 BRINE_WT                               NUMBER
 UNLOAD_DAY                             DATE
 UNLOAD_PORT                            VARCHAR2(20)
```

CE_IMP_LAND_LOG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 SKIPPER                                VARCHAR2(30)
 INCOMPLETE                             VARCHAR2(10)
 AUTH_HOLDER                            VARCHAR2(50)
 ADDRESS                                VARCHAR2(200)
 FISH_NIGHTS                            NUMBER(38)
 CARTON_TOT                             NUMBER
 PRAWN_WT_TOT                           NUMBER
 BRINE_WT_TOT                           NUMBER
 LANDED_WT_TOT                          NUMBER
```

CE_IMP_SHOT

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(10)
 DAY                                    DATE
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 SHOT                          NOT NULL NUMBER(38)
 BLOCK_NO1                              VARCHAR2(10)
 BLOCK_NO2                              VARCHAR2(10)
 BLOCK_NO3                              VARCHAR2(10)
 BLOCK_NO4                              VARCHAR2(10)
 BLOCK_CNT                              NUMBER(38)
 BLOCK_MULTI                            VARCHAR2(20)
 START_HR                               NUMBER(38)
 START_MIN                              NUMBER(38)
 END_HR                                 NUMBER(38)
 END_MIN                                NUMBER(38)
 TRAWL_MINS                             NUMBER(38)
 CATCH_LB                               NUMBER
 DEPTH_FATHOMS                          NUMBER
 CATCH_KG                               NUMBER
 DEPTH_METRES                           NUMBER
 TEMP                                   NUMBER
 MID_LAT_DEG                            NUMBER
 MID_LAT_MIN                            NUMBER
 MID_LAT_SEC                            NUMBER
 MID_LONG_DEG                           NUMBER
 MID_LONG_MIN                           NUMBER
 MID_LONG_SEC                           NUMBER
 NOTE                                   VARCHAR2(200)
```

CE_IMP_SHOT_LOG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
 DAY                                    DATE
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 SKIPPER                                VARCHAR2(30)
 INCOMPLETE                             VARCHAR2(10)
 SHOT_TOTAL                             NUMBER(38)
 AVE_TRAWL_SPEED                        NUMBER
 CARTON_NO                              NUMBER
 CARTON_WT                              NUMBER
 CARTON_WT2                             NUMBER
 CARTON_WT3                             NUMBER
 CARTON_WT4                             NUMBER
 CARTON_WT5                             NUMBER
 EST_ACCURACY                           NUMBER
 BYC_CALAMARY_KG                        NUMBER
 BYC_BUGS_KG                            NUMBER
 TEMP                                   NUMBER
 DAILY_VS_GRADE                         NUMBER
 RELIABILITY                            VARCHAR2(10)
 TRAWL_MINS_TOT                         NUMBER
 CATCH_KG_TOT                           NUMBER
 CARTON_NO_TOT                          NUMBER
 CARTON_KG_TOT                          NUMBER
 LOG_SHEET_NO                           VARCHAR2(10)
 FORM_ID                                VARCHAR2(30)
```

CE_LAND_DETAIL

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 ORDER_NO                      NOT NULL NUMBER(38)
 CARTON_NO                              NUMBER
 CARTON_WT                              NUMBER
 PRAWN_WT                               NUMBER
 BRINE_WT                               NUMBER
 UNLOAD_DAY                             DATE
 UNLOAD_PORT                            VARCHAR2(20)
```

CE_LAND_DETAIL_A2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 MONTH                         NOT NULL VARCHAR2(12)
 YEAR                          NOT NULL NUMBER(38)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 DAY                           NOT NULL DATE
 PORT_OF_LANDING                        VARCHAR2(30)
 GRID                                   VARCHAR2(30)
 CODE                                   VARCHAR2(30)
 QTY_LANDED                             NUMBER
 NOTE                                   VARCHAR2(100)
```

CE_LAND_DETAIL_A3

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 MONTH                         NOT NULL VARCHAR2(12)
 YEAR                          NOT NULL NUMBER(38)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 DAY_NO                        NOT NULL NUMBER(38)
 DAY                                    DATE
 GRID                                   VARCHAR2(30)
 CATCH_KG                               NUMBER
 EFFORT_MINS                            NUMBER
 CE                                     NUMBER
 NOTE                                   VARCHAR2(100)
```

CE_LAND_DETAIL_A6B

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 UNLOAD_DAY                             DATE
 ORDER_NO                      NOT NULL NUMBER(38)
 KG_UNLOADED                            NUMBER
 UNLOAD_PORT                            VARCHAR2(20)
 PURCHASER                              VARCHAR2(30)
 NOTE                                   VARCHAR2(100)
```

CE_LAND_DETAIL_A6F

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 UNLOAD_DAY                             DATE
 ORDER_NO                      NOT NULL NUMBER(38)
 CARTON_NO                              NUMBER
 CARTON_WT                              NUMBER
 UNLOAD_PORT                            VARCHAR2(20)
 PURCHASER                              VARCHAR2(30)
```

```
 NOTE                                    VARCHAR2(100)
```

CE_LAND_LOG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                   NOT NULL VARCHAR2(30)
 SKIPPER                                VARCHAR2(30)
 INCOMPLETE                             VARCHAR2(10)
 AUTH_HOLDER                            VARCHAR2(50)
 ADDRESS                                VARCHAR2(200)
 FISH_NIGHTS                            NUMBER(38)
 CARTON_TOT                             NUMBER
 PRAWN_WT_TOT                           NUMBER
 BRINE_WT_TOT                           NUMBER
 LANDED_WT_TOT                          NUMBER
 SOURCE                                 VARCHAR2(50)
```

CE_LAND_LOG_A2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 MONTH                         NOT NULL VARCHAR2(12)
 YEAR                          NOT NULL NUMBER(38)
 AUTH_HOLDER                            VARCHAR2(50)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 ADDRESS                                VARCHAR2(200)
 SKIPPER                                VARCHAR2(30)
 TOTAL_KG                               NUMBER
 PURCHASER1                             VARCHAR2(30)
 P_CODE1                                VARCHAR2(30)
 KG_COOKED1                             NUMBER
 KG_GREEN1                              NUMBER
 PURCHASER2                             VARCHAR2(30)
 P_CODE2                                VARCHAR2(30)
 KG_COOKED2                             NUMBER
 KG_GREEN2                              NUMBER
 PURCHASER3                             VARCHAR2(30)
 P_CODE3                                VARCHAR2(30)
 KG_COOKED3                             NUMBER
 KG_GREEN3                              NUMBER
 PURCHASER4                             VARCHAR2(30)
 P_CODE4                                VARCHAR2(30)
 KG_COOKED4                             NUMBER
 KG_GREEN4                              NUMBER
 PURCHASER5                             VARCHAR2(30)
 P_CODE5                                VARCHAR2(30)
 KG_COOKED5                             NUMBER
 KG_GREEN5                              NUMBER
 PURCHASER6                             VARCHAR2(30)
 P_CODE6                                VARCHAR2(30)
 KG_COOKED6                             NUMBER
 KG_GREEN6                              NUMBER
 PURCHASER7                             VARCHAR2(30)
 P_CODE7                                VARCHAR2(30)
 KG_COOKED7                             NUMBER
 KG_GREEN7                              NUMBER
 CREW1                                  VARCHAR2(30)
 CREW2                                  VARCHAR2(30)
 CREW3                                  VARCHAR2(30)
 CREW4                                  VARCHAR2(30)
 CREW5                                  VARCHAR2(30)
 CREW6                                  VARCHAR2(30)
 CREW7                                  VARCHAR2(30)
 CREW8                                  VARCHAR2(30)
 CREW1_DAYS                             NUMBER(38)
 CREW2_DAYS                             NUMBER(38)
 CREW3_DAYS                             NUMBER(38)
 CREW4_DAYS                             NUMBER(38)
 CREW5_DAYS                             NUMBER(38)
 CREW6_DAYS                             NUMBER(38)
 CREW7_DAYS                             NUMBER(38)
 CREW8_DAYS                             NUMBER(38)
 TOTAL_CREW_DAYS                        NUMBER
 ACTUAL_FISH_DAYS                       NUMBER
 NOTE                                   VARCHAR2(200)
 SOURCE                                 VARCHAR2(50)
 REG_NO                                 VARCHAR2(30)
 MONTH_NO                               VARCHAR2(2)
```

CE_LAND_LOG_A3

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 MONTH                         NOT NULL VARCHAR2(12)
 YEAR                          NOT NULL NUMBER(38)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 TOTAL_KG                               NUMBER
 TOTAL_MINS                             NUMBER
 NOTE                                   VARCHAR2(200)
 SOURCE                                 VARCHAR2(50)
 REG_NO                                 VARCHAR2(30)
 MONTH_NO                               VARCHAR2(2)
```

CE_LAND_LOG_A6

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 SKIPPER                                VARCHAR2(30)
 FREEZER_CARTON_TOT                     NUMBER
 FREEZER_CARTON_KG                      NUMBER
 BRINE_WT_TOT                           NUMBER
 SOURCE                                 VARCHAR2(50)
 NOTE                                   VARCHAR2(200)
 AVE_CARTON_WT                          NUMBER
 REG_NO                                 VARCHAR2(30)
```

CE_LOAD_DAT

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 FROM_DATE                              DATE
 TO_DATE                                DATE
 DATE_DATE                              DATE
 CARTONS                                NUMBER
 QUANT_KG                               NUMBER
 GREEN_KG                               NUMBER
 COOKED_KG                              NUMBER
 PURCH_CODE                             VARCHAR2(10)
```

CE_LOAD_DAT2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 FROM_DATE                              DATE
 TO_DATE                                DATE
 DATE_DATE                              DATE
 CARTONS                                VARCHAR2(10)
 QUANT_KG                               VARCHAR2(10)
 GREEN_KG                               VARCHAR2(10)
 COOKED_KG                              VARCHAR2(10)
 PURCH_CODE                             VARCHAR2(10)
```

CE_LOAD_DAT_RAW

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 FROM_DATE                              VARCHAR2(30)
 TO_DATE                                VARCHAR2(30)
 DATE_DATE                              VARCHAR2(30)
 CARTONS                                VARCHAR2(10)
 QUANT_KG                               VARCHAR2(10)
 GREEN_KG                               VARCHAR2(10)
 COOKED_KG                              VARCHAR2(10)
 PURCH_CODE                             VARCHAR2(10)
```

CE_LOAD_DAY

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 VESL_NAME                              VARCHAR2(30)
 FROM_DATE                              DATE
 TO_DATE                                DATE
 DATE_DATE                              DATE
 BLANK                                  VARCHAR2(10)
```

CE_LOAD_DAY2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 VESL_NAME                              VARCHAR2(30)
 FROM_DATE                              DATE
 TO_DATE                                DATE
 DATE_DATE                              DATE
 BLANK                                  VARCHAR2(10)
```

CE_LOAD_DAY_NODUP

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 VESL_NAME                              VARCHAR2(30)
 FROM_DATE                              VARCHAR2(10)
 TO_DATE                                VARCHAR2(10)
 DATE_DATE                              VARCHAR2(10)
 BLANK                                  VARCHAR2(10)
```

CE_LOAD_DAY_ORIG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 VESL_NAME                              VARCHAR2(30)
 FROM_DATE                              VARCHAR2(10)
 TO_DATE                                VARCHAR2(10)
 DATE_DATE                              VARCHAR2(10)
 BLANK                                  VARCHAR2(10)
```

CE_LOAD_DAY_RAW

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 VESL_NAME                              VARCHAR2(30)
 FROM_DATE                              VARCHAR2(30)
 TO_DATE                                VARCHAR2(30)
 DATE_DATE                              VARCHAR2(30)
 BLANK                                  VARCHAR2(10)
```

CE_LOAD_MON

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 MONTH_FROM                             VARCHAR2(10)
 MONTH_TO                               VARCHAR2(10)
 YEAR                                   VARCHAR2(10)
 LICENCE_NO                             VARCHAR2(10)
```

```
 FROM_DATE                                  DATE
 TO_DATE                                    DATE
 SNAME                                      VARCHAR2(30)
 VESL_NAME                                  VARCHAR2(30)
 SKIPPER                                    VARCHAR2(30)
 PFISH_EXP                                  NUMBER(38)
 TOT_CART                                   NUMBER
 TOT_KG                                     NUMBER
 TOT_GREEN                                  NUMBER
 TOT_COOKED                                 NUMBER
 FISH_DAYS                                  NUMBER(38)
 TOT_CREWD                                  NUMBER(38)
```

CE_LOAD_MON2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 MONTH_FROM                             VARCHAR2(10)
 MONTH_TO                               VARCHAR2(10)
 YEAR                                   VARCHAR2(10)
 LICENCE_NO                             VARCHAR2(10)
 FROM_DATE                              DATE
 TO_DATE                                DATE
 SNAME                                  VARCHAR2(30)
 VESL_NAME                              VARCHAR2(30)
 SKIPPER                                VARCHAR2(30)
 PFISH_EXP                              VARCHAR2(10)
 TOT_CART                               VARCHAR2(10)
 TOT_KG                                 VARCHAR2(10)
 TOT_GREEN                              VARCHAR2(10)
 TOT_COOKED                             VARCHAR2(10)
 FISH_DAYS                              VARCHAR2(10)
 TOT_CREWD                              VARCHAR2(10)
```

CE_LOAD_MON_ORIG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 MONTH_FROM                             VARCHAR2(10)
 MONTH_TO                               VARCHAR2(10)
 YEAR                                   VARCHAR2(10)
 LICENCE_NO                             VARCHAR2(10)
 FROM_DATE                              VARCHAR2(10)
 TO_DATE                                VARCHAR2(10)
 SNAME                                  VARCHAR2(30)
 VESL_NAME                              VARCHAR2(30)
 SKIPPER                                VARCHAR2(30)
 PFISH_EXP                              VARCHAR2(10)
 TOT_CART                               VARCHAR2(10)
 TOT_KG                                 VARCHAR2(10)
 TOT_GREEN                              VARCHAR2(10)
 TOT_COOKED                             VARCHAR2(10)
 FISH_DAYS                              VARCHAR2(10)
 TOT_CREWD                              VARCHAR2(10)
```

CE_LOAD_MON_RAW

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 MONTH_FROM                             VARCHAR2(10)
 MONTH_TO                               VARCHAR2(10)
 YEAR                                   VARCHAR2(10)
 LICENCE_NO                             VARCHAR2(10)
 FROM_DATE                              VARCHAR2(30)
 TO_DATE                                VARCHAR2(30)
 SNAME                                  VARCHAR2(30)
 VESL_NAME                              VARCHAR2(30)
 SKIPPER                                VARCHAR2(30)
 PFISH_EXP                              VARCHAR2(10)
 TOT_CART                               VARCHAR2(10)
 TOT_KG                                 VARCHAR2(10)
 TOT_GREEN                              VARCHAR2(10)
 TOT_COOKED                             VARCHAR2(10)
 FISH_DAYS                              VARCHAR2(10)
 TOT_CREWD                              VARCHAR2(10)
```

CE_LOAD_PRCOMLOG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 RECORD                                 NUMBER(38)
 LOTNO                                  NUMBER(38)
 REGION                                 VARCHAR2(3)
 SDATE                                  VARCHAR2(12)
 TYPE                                   VARCHAR2(3)
 BLOCK                                  VARCHAR2(12)
 RELIAB                                 VARCHAR2(1)
 VESSEL                                 VARCHAR2(30)
 NOF                                    NUMBER
 NOM                                    NUMBER
 WTF                                    NUMBER
 WTM                                    NUMBER
 TOTWT                                  NUMBER
```

CE_LOAD_PRCOMSAM

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 RECORD                                 NUMBER(38)
 LOTNO                                  NUMBER(38)
 SDATE                                  VARCHAR2(12)
 BLOCK                                  VARCHAR2(12)
 VESSEL                                 VARCHAR2(30)
 SIZE_MM                                NUMBER
 NOF                                    NUMBER
 NOM                                    NUMBER
```

CE_LOAD_SHO

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              DATE
 TO_DATE                                DATE
 DATE_DATE                              DATE
 LICENCE_NO                             VARCHAR2(10)
 SHOT                                   NUMBER(38)
 BLOCK_NO                               VARCHAR2(10)
 START_TIME                             VARCHAR2(10)
 DURATION                               NUMBER
 CATCH_KG                               NUMBER
 ADJUST                                 NUMBER
```

CE_LOAD_SHO2

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              DATE
 TO_DATE                                DATE
 DATE_DATE                              DATE
 LICENCE_NO                             VARCHAR2(10)
 SHOT                                   VARCHAR2(10)
 BLOCK_NO                               VARCHAR2(10)
 START_TIME                             VARCHAR2(10)
 DURATION                               VARCHAR2(10)
 CATCH_KG                               VARCHAR2(10)
 ADJUST                                 VARCHAR2(10)
```

CE_LOAD_SHO_DUP

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 LICENCE_NO                             VARCHAR2(10)
 FROM_DATE                              VARCHAR2(10)
 DATE_DATE                              VARCHAR2(10)
 SHOT                                   VARCHAR2(10)
 BLOCK_NO                               VARCHAR2(10)
 CNT                                    NUMBER
```

CE_LOAD_SHO_NODUP

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              VARCHAR2(10)
 TO_DATE                                VARCHAR2(10)
 DATE_DATE                              VARCHAR2(10)
 LICENCE_NO                             VARCHAR2(10)
 SHOT                                   VARCHAR2(10)
 BLOCK_NO                               VARCHAR2(10)
 START_TIME                             VARCHAR2(10)
 DURATION                               VARCHAR2(10)
 CATCH_KG                               VARCHAR2(10)
 ADJUST                                 VARCHAR2(10)
```

CE_LOAD_SHO_ORIG

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              VARCHAR2(10)
 TO_DATE                                VARCHAR2(10)
 DATE_DATE                              VARCHAR2(10)
 LICENCE_NO                             VARCHAR2(10)
 SHOT                                   VARCHAR2(10)
 BLOCK_NO                               VARCHAR2(10)
 START_TIME                             VARCHAR2(10)
 DURATION                               VARCHAR2(10)
 CATCH_KG                               VARCHAR2(10)
 ADJUST                                 VARCHAR2(10)
```

CE_LOAD_SHO_RAW

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              VARCHAR2(30)
 TO_DATE                                VARCHAR2(30)
 DATE_DATE                              VARCHAR2(30)
 LICENCE_NO                             VARCHAR2(10)
 SHOT                                   VARCHAR2(10)
 BLOCK_NO                               VARCHAR2(10)
 START_TIME                             VARCHAR2(10)
 DURATION                               VARCHAR2(10)
 CATCH_KG                               VARCHAR2(30)
 ADJUST                                 VARCHAR2(30)
```

CE_PRICE

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 BUYER                         NOT NULL VARCHAR2(80)
 PERIOD_ID                     NOT NULL VARCHAR2(30)
 FROM_DATE                              DATE
 TO_DATE                                DATE
 YEAR                                   NUMBER(38)
 MONTH                                  VARCHAR2(3)
 NOTE                                   VARCHAR2(80)
```

CE_PRICE_DETAIL

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 BUYER                         NOT NULL VARCHAR2(80)
 PERIOD_ID                     NOT NULL VARCHAR2(30)
 GRADE                         NOT NULL VARCHAR2(30)
 PER_KG_CNT                             VARCHAR2(30)
 WEIGHT_RANGE                           VARCHAR2(30)
 PACK                                   VARCHAR2(30)
 FORM                                   VARCHAR2(30)
 PRICE                                  NUMBER
 NOTE                                   VARCHAR2(30)
 COL1                                   VARCHAR2(30)
 COL2                                   VARCHAR2(30)
 COL3                                   VARCHAR2(30)
```

```
 GRADE1                                 VARCHAR2(10)
 GRADE2                                 VARCHAR2(10)
 GRADE3                                 VARCHAR2(10)
 GRADE4                                 VARCHAR2(10)
 GRADE5                                 VARCHAR2(10)
 GRADE6                                 VARCHAR2(10)
 GRADE7                                 VARCHAR2(10)
 WEIGHT_HI                              NUMBER
 WEIGHT_LO                              NUMBER
 DATA_ENTRY_ORDER                       NUMBER(38)
```

CE_RECORD

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 FP                             NOT NULL VARCHAR2(20)
 MONTH                                   VARCHAR2(12)
 YEAR                                    NUMBER(38)
 NOTE                                    VARCHAR2(200)
```

CE_RECORD_DETAIL

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 FP                             NOT NULL VARCHAR2(20)
 MONTH                                   VARCHAR2(12)
 YEAR                                    NUMBER(38)
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 VESSEL_NAME                             VARCHAR2(30)
 DAILY                                   VARCHAR2(1)
 MONTHLY                                 VARCHAR2(1)
 NOTE                                    VARCHAR2(200)
```

CE_SHOT

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 FP                             NOT NULL VARCHAR2(20)
 DAY                            NOT NULL DATE
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 SHOT                           NOT NULL NUMBER(38)
 BLOCK_NO1                      NOT NULL VARCHAR2(10)
 BLOCK_NO2                               VARCHAR2(10)
 BLOCK_NO3                               VARCHAR2(10)
 BLOCK_NO4                               VARCHAR2(10)
 BLOCK_CNT                               NUMBER(38)
 BLOCK_MULTI                             VARCHAR2(20)
 START_HR                                NUMBER(38)
 START_MIN                               NUMBER(38)
 START_SEC                               NUMBER(38)
 END_HR                                  NUMBER(38)
 END_MIN                                 NUMBER(38)
 END_SEC                                 NUMBER(38)
 TRAWL_MINS                              NUMBER(38)
 CATCH_LB                                NUMBER
 DEPTH_FATHOMS                           NUMBER
 CATCH_KG                                NUMBER
 DEPTH_METRES                            NUMBER
 TEMP                                    NUMBER
 MID_LAT_DEG                             NUMBER
 MID_LAT_MIN                             NUMBER
 MID_LAT_SEC                             NUMBER
 MID_LONG_DEG                            NUMBER
 MID_LONG_MIN                            NUMBER
 MID_LONG_SEC                            NUMBER
 CE_COMMENT                              VARCHAR2(200)
```

CE_SHOT_A10

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 DAY                            NOT NULL DATE
 FP                             NOT NULL VARCHAR2(20)
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 SHOT                           NOT NULL NUMBER(38)
 GRID_REF                                VARCHAR2(20)
 RPM                                     NUMBER
 START_HR                                NUMBER(38)
 START_MIN                               NUMBER(38)
 DURATION_MINS                           NUMBER
 EST_CATCH_KG                            NUMBER
 NOTE                                    VARCHAR2(100)
 DEPTH                                   NUMBER
```

CE_SHOT_A4

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 YEAR                           NOT NULL NUMBER(38)
 MONTH                          NOT NULL VARCHAR2(10)
 DAY_NO                         NOT NULL NUMBER(38)
 DAY                                     DATE
 GRID                                    VARCHAR2(10)
 CATCH_KG                                NUMBER
 CATCH_MINS                              NUMBER
 BLOCK1                                  VARCHAR2(10)
 CATCH_KG1                               NUMBER
 EFFORT1                                 NUMBER
 BLOCK2                                  VARCHAR2(10)
 CATCH_KG2                               NUMBER
 EFFORT2                                 NUMBER
 BLOCK3                                  VARCHAR2(10)
 CATCH_KG3                               NUMBER
 EFFORT3                                 NUMBER
 NOTE                                    VARCHAR2(10)
 GRID2                                   VARCHAR2(10)
 GRID2_CATCH_KG                          NUMBER
 GRID2_CATCH_EFFORT                      NUMBER
 BLOCK4                                  VARCHAR2(10)
 CATCH_KG4                               NUMBER
 EFFORT4                                 NUMBER
```

CE_SHOT_A8

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 FP                             NOT NULL VARCHAR2(20)
 DAY                            NOT NULL DATE
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 SHOT                           NOT NULL NUMBER(38)
 BLOCK_NO1                      NOT NULL VARCHAR2(10)
 BLOCK_NO2                               VARCHAR2(10)
 BLOCK_NO3                               VARCHAR2(10)
 BLOCK_NO4                               VARCHAR2(10)
 BLOCK_CNT                               NUMBER(38)
 BLOCK_MULTI                             VARCHAR2(20)
 START_HR                                NUMBER(38)
 START_MIN                               NUMBER(38)
 END_HR                                  NUMBER(38)
 END_MIN                                 NUMBER(38)
 TRAWL_MINS                              NUMBER(38)
 FREEZER_CARTON_NO                       NUMBER
 FREEZER_KG                              NUMBER
 BRINE_KG                                NUMBER
 DEPTH_FATHOMS                           NUMBER
 DEPTH_METRES                            NUMBER
 TIDE                                    VARCHAR2(1)
 TRAWLED                                 VARCHAR2(1)
 TEMP                                    NUMBER
 NOTE                                    VARCHAR2(200)
 TAG_FLAG                                VARCHAR2(1)
```

CE_SHOT_LOG

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 FP                             NOT NULL VARCHAR2(20)
 DAY                            NOT NULL DATE
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 VESSEL_NAME                    NOT NULL VARCHAR2(30)
 SKIPPER                                 VARCHAR2(30)
 INCOMPLETE                              VARCHAR2(10)
 SHOT_TOTAL                              NUMBER(38)
 AVE_TRAWL_SPEED                         NUMBER
 CARTON_NO                               NUMBER
 CARTON_WT                               NUMBER
 EST_ACCURACY                            NUMBER
 BYC_CALAMARY_KG                         NUMBER
 BYC_BUGS_KG                             NUMBER
 TEMP                                    NUMBER
 DAILY_VS_GRADE                          NUMBER
 RELIABILITY                             VARCHAR2(10)
 TRAWL_MINS_TOT                          NUMBER
 CATCH_KG_TOT                            NUMBER
 CARTON_NO_TOT                           NUMBER
 CARTON_KG_TOT                           NUMBER
 LOG_SHEET_NO                            VARCHAR2(10)
 FORM_ID                                 VARCHAR2(30)
 SOURCE                                  VARCHAR2(50)
```

CE_SHOT_LOG_A4

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 VESSEL_NAME                             VARCHAR2(30)
 RIG                                     VARCHAR2(30)
 SKIPPER                                 VARCHAR2(30)
 REGION                                  VARCHAR2(30)
 EXP                                     VARCHAR2(30)
 REL                                     VARCHAR2(30)
 YEAR                           NOT NULL NUMBER(38)
 MONTH                          NOT NULL VARCHAR2(10)
 TRIP_FROM                               DATE
 TRIP_TO                                 DATE
 BRINE_KG                                NUMBER
 FREEZER_KG                              NUMBER
 NOTE                                    VARCHAR2(100)
 MONTHLY_KG                              NUMBER
 SOURCE                                  VARCHAR2(50)
 RIG_CODE                                VARCHAR2(3)
 SKIPPER_CODE                            VARCHAR2(3)
 EXP_YRS                                 NUMBER(38)
 REL_CODE                                VARCHAR2(3)
 MONTH_NO                                VARCHAR2(2)
```

CE_SHOT_LOG_DETAIL

```
 Name                           Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                           NOT NULL VARCHAR2(1)
 FP                             NOT NULL VARCHAR2(20)
 DAY                            NOT NULL DATE
 FORM                                    VARCHAR2(30)
 LICENCE_NO                     NOT NULL VARCHAR2(10)
 WEATHER                                 VARCHAR2(100)
 WIND_DIRECTION                          VARCHAR2(100)
 WIND_SPEED                              VARCHAR2(50)
 NOTES                                   VARCHAR2(200)
 TOTAL_MINS                              NUMBER
 TOTAL_FREEZER_CARTONS                   NUMBER
 TOTAL_FREEZER_KG                        NUMBER
 TOTAL_BRINE_KG                          NUMBER
 TOTAL_HOURS_UNDER_WAY                   NUMBER
 TOTAL_KG                                NUMBER
 LANDING_PORT                            VARCHAR2(30)
 QTY_KG                                  NUMBER
 MAJOR_GRID_REF                          VARCHAR2(20)
 BLOCK                                   VARCHAR2(20)
 REG_NO                                  VARCHAR2(30)
```

CE_TAG_A8

```
 Name                           Null?    Type
```

```
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(30)
 DAY                           NOT NULL DATE
 LICENCE_NO                    NOT NULL VARCHAR2(30)
 VESSEL_NAME                            VARCHAR2(30)
```

CE_TAG_DETAIL_A8

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(30)
 DAY                           NOT NULL DATE
 LICENCE_NO                    NOT NULL VARCHAR2(30)
 VESSEL_NAME                            VARCHAR2(30)
 ID                            NOT NULL VARCHAR2(20)
 BLOCK                                  VARCHAR2(10)
 SHOT                                   NUMBER
 TAG_NO                                 VARCHAR2(30)
 STATUS                                 VARCHAR2(10)
 NOTE                                   VARCHAR2(200)
```

CE_TMP_DUP_SHOT

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                                   VARCHAR2(1)
 FP                                     VARCHAR2(10)
 LICENCE_NO                             VARCHAR2(10)
 DAY                                    DATE
 SHOT                                   NUMBER(38)
 BLOCK_NO                               VARCHAR2(10)
 COUNT_ROWS                             NUMBER
```

CE_TMP_SHOT_DELETED

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 FROM_DATE                              DATE
 TO_DATE                                DATE
 DAY                                    DATE
 LICENCE_NO                             VARCHAR2(10)
 SHOT                                   NUMBER(38)
 BLOCK_NO                               VARCHAR2(10)
 START_TIME                             VARCHAR2(10)
 DURATION                               NUMBER
 CATCH_KG_ACTUAL                        NUMBER
 CATCH_KG_EXPECT                        NUMBER
 ADJUST                                 NUMBER
 AREA                                   VARCHAR2(1)
 FP                                     VARCHAR2(10)
```

CE_VESSEL

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 YEAR                                   NUMBER(38)
 MONTH_FROM                             VARCHAR2(10)
 MONTH_TO                               VARCHAR2(10)
 FROM_DATE                              DATE
 TO_DATE                                DATE
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 OWNER                                  VARCHAR2(30)
 SKIPPER                                VARCHAR2(30)
 YRS_FISH_EXP                           NUMBER(38)
 FISH_DAYS                              NUMBER(38)
 CREW_DAYS                              NUMBER(38)
 AREA                          NOT NULL VARCHAR2(1)
 FP                            NOT NULL VARCHAR2(20)
```

CE_VESSEL_CALC

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                                   VARCHAR2(1)
 LICENCE_NO                             VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 CALC_DATE                              DATE
 MA                                     NUMBER
 LENGTH_OA                              NUMBER
 LENGTH_LWL                             NUMBER
 LENGTH_BP                              NUMBER
 BREADTH                                NUMBER
 DEPTH                                  NUMBER
 DISPLACEMENT                           NUMBER
 DISP_NOTE                              NUMBER
 LIGHTSHIP1                             NUMBER
 CAP_FRESH_WATER                        NUMBER
 CAP_FUEL_OIL                           NUMBER
 BRINE_TANKS                            NUMBER
 FREEZER                                NUMBER
 TOTAL_DEAD_WEIGHT                      NUMBER
 LIGHTSHIP2                             NUMBER
 DISPLACEMENT2                          NUMBER
 FUEL40                                 NUMBER
 FUEL40_BRINE                           NUMBER
 FUEL40_FREEZER                         NUMBER
 FUEL40_LIGHTSHIP                       NUMBER
 FUEL60                                 NUMBER
 FUEL60_BRINE                           NUMBER
 FUEL60_FREEZER                         NUMBER
 FUEL60_LIGHTSHIP                       NUMBER
 FUEL80                                 NUMBER
 FUEL80_BRINE                           NUMBER
 FUEL80_FREEZER                         NUMBER
 FUEL80_LIGHTSHIP                       NUMBER
 DISPLACEMENT_MASS                      NUMBER
 GROSS_TONNAGE                          NUMBER
 ENGINE_MAKE_MODEL                      VARCHAR2(10)
 ENGINE_YEAR                            VARCHAR2(10)
 CYLINDERS                              NUMBER(38)
 RPM                                    NUMBER
 KW_MAX                                 VARCHAR2(30)
 BHP                                    NUMBER
 KW_AT_SHAFT                            NUMBER
 GEN_AUX_BY                             VARCHAR2(30)
 REDUCTION                              VARCHAR2(30)
 REV_GEAR_TYPE                          VARCHAR2(30)
 PROP_DIA_PITCH                         VARCHAR2(30)
 PROP_BLADES                            NUMBER(38)
 PROP_FIXED                             VARCHAR2(1)
 AUX_ENGINE1                            VARCHAR2(50)
 AUX_ENGINE2                            VARCHAR2(50)
 AUX_ENGINE3                            VARCHAR2(50)
 PREV_SURVEY_DATE                       DATE
 IDENTIFIER                             VARCHAR2(30)
 NOTE                                   VARCHAR2(200)
 SOURCE                                 VARCHAR2(50)
```

CE_VESSEL_EQUIP

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 VESSEL_NAME                            VARCHAR2(30)
 START_DATE                    NOT NULL DATE
 END_DATE                               DATE
 OWNER                                  VARCHAR2(30)
 ADDRESS                                VARCHAR2(50)
 VESSEL_LENGTH                          NUMBER
 MAX_BREADTH                            NUMBER
 DRAFT                                  NUMBER
 GROSS_TONNAGE                          NUMBER
 TOTAL_MASS                             NUMBER
 GEAR_CONFIG                            VARCHAR2(30)
 HEADLINE_LENGTH                        NUMBER
 BOARD_TYPE                             VARCHAR2(30)
 BOARD_LENGTH                           NUMBER
 BOARD_HEIGHT                           NUMBER
 BOARD_CONSTRUCTION                     VARCHAR2(30)
 NET_MESH_TYPE                          VARCHAR2(30)
 NET_MESH_SIZE                          VARCHAR2(30)
 CODEND                                 VARCHAR2(30)
 WINGS_AND_BELLY                        VARCHAR2(30)
 POWER_CBHP_RATING                      VARCHAR2(30)
 KW_POWER                               NUMBER
 RPM                                    NUMBER
 ENGINE_MANUFACTURER                    VARCHAR2(30)
 ENGINE_MODEL                           VARCHAR2(30)
 NOZZLE                                 VARCHAR2(30)
 PROPELLOR                              VARCHAR2(30)
 HOPPER                                 VARCHAR2(30)
 HOPPER_MANUFACTURER                    VARCHAR2(30)
 HOPPER_MODEL                           VARCHAR2(30)
 GRADER                                 VARCHAR2(30)
 GRADER_MANUFACTURER                    VARCHAR2(30)
 GEARBOX_RATIO                          VARCHAR2(30)
 CRAB_RACKS                             VARCHAR2(30)
 CRAB_BAGS                              VARCHAR2(30)
 AVE_TRAWL_SPEED                        NUMBER
 NET_SPREAD_PCT                         NUMBER
 GPS_MANUFACTURER                       VARCHAR2(30)
 GPS_MODEL                              VARCHAR2(30)
 PLOTTER_MANUFACTURER                   VARCHAR2(30)
 PLOTTER_MODEL                          VARCHAR2(30)
 GPS_SOFTWARE_MANUFACTURER              VARCHAR2(30)
 GPS_SOFTWARE_MODEL                     VARCHAR2(30)
 SONAR_MANUFACTURER                     VARCHAR2(30)
 SONAR_MODEL                            VARCHAR2(30)
 BRINE_TANK_CAPACITY                    VARCHAR2(30)
 SNAP_FREEZE_CAPACITY                   VARCHAR2(30)
 MAIN_FREEZER_CAPACITY                  VARCHAR2(30)
 RADAR_MANUFACTURER                     VARCHAR2(30)
 RADAR_MODEL                            VARCHAR2(30)
 ECHO_SOUNDER_MANUFACTURER              VARCHAR2(30)
 ECHO_SOUNDER_MODEL                     VARCHAR2(30)
 NOTE                                   VARCHAR2(100)
 SOURCE                                 VARCHAR2(50)
```

CE_VESSEL_EQUIP_OLD

```
 Name                          Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                          NOT NULL VARCHAR2(1)
 LICENCE_NO                    NOT NULL VARCHAR2(10)
 LICENCEE_NAME                          VARCHAR2(30)
 VESSEL_NAME                            VARCHAR2(30)
 START_DATE                    NOT NULL DATE
 END_DATE                               DATE
 CONSTRUCTION_STEEL                     VARCHAR2(1)
 CONSTRUCTION_WOOD                      VARCHAR2(1)
 CONSTRUCTION_GRP                       VARCHAR2(1)
 VESSEL_LENGTH                          NUMBER
 MAX_BREADTH                            NUMBER
 MOULD_DEPTH                            NUMBER
 GROSS_TONNAGE                          NUMBER
 ENGINE_MAKE                            VARCHAR2(30)
 ENGINE_MODEL                           VARCHAR2(30)
 POWER_CBHP_RATING                      VARCHAR2(30)
 KW_POWER                               NUMBER
 RPM                                    NUMBER
 NOZZLE                                 VARCHAR2(1)
 RADIO_MARINE_VHF                       VARCHAR2(1)
 RADIO_UHF                              VARCHAR2(1)
 RADIO_VHF                              VARCHAR2(1)
 RADIO_HF                               VARCHAR2(1)
 RADIO_CB                               VARCHAR2(1)
 RADIO_OTHER                            VARCHAR2(50)
 ECHO_SOUNDER_COL_MAKE                  VARCHAR2(30)
 ECHO_SOUNDER_COL_MODEL                 VARCHAR2(30)
 ECHO_SOUNDER_COL_FREQ                  VARCHAR2(30)
 ECHO_SOUNDER_BW_MAKE                   VARCHAR2(30)
 ECHO_SOUNDER_BW_MODEL                  VARCHAR2(30)
 ECHO_SOUNDER_BW_FREQ                   VARCHAR2(30)
 RADAR_COL_MAKE                         VARCHAR2(30)
```

```
 RADAR_COL_MODEL                               VARCHAR2(30)
 RADAR_COL_RANGE                               VARCHAR2(30)
 RADAR_BW_MAKE                                 VARCHAR2(30)
 RADAR_BW_MODEL                                VARCHAR2(30)
 RADAR_BW_RANGE                                VARCHAR2(30)
 SATNAV_MAKE                                   VARCHAR2(30)
 SATNAV_MODEL                                  VARCHAR2(30)
 PLOTTER_COLOUR                                VARCHAR2(1)
 SPEED_LOG                                     VARCHAR2(1)
 AUTOPILOT_MAKE                                VARCHAR2(30)
 AUTOPILOT_MODEL                               VARCHAR2(30)
 BLAST_FREEZER                                 VARCHAR2(1)
 IQF                                           VARCHAR2(1)
 BRINE                                         VARCHAR2(1)
 TOTAL_BRINE_CAPACITY                          NUMBER
 BLAST_FREEZER_CARTONS                         NUMBER
 BLAST_FREEZER_TONNES                          NUMBER
 IQF_CARTONS                                   NUMBER
 IQF_TONNES                                    NUMBER
 BRINE_CARTONS                                 NUMBER
 BRINE_TONNES                                  NUMBER
 NET_RIG                                       VARCHAR2(30)
 NET_RIG_OTHER                                 VARCHAR2(30)
 NET_GUNDRY                                    VARCHAR2(1)
 NET_FLORIDA                                   VARCHAR2(1)
 NET_SANDAKAN                                  VARCHAR2(1)
 NET_OTHER                                     VARCHAR2(30)
 BOARD_LENGTH                                  NUMBER
 BOARD_HEIGHT                                  NUMBER
 BOARD_TYPE_FULL                               VARCHAR2(1)
 BOARD_TYPE_SLOTTED                            VARCHAR2(1)
 BOARD_TYPE_OTHER                              VARCHAR2(30)
 BOARD_WOOD                                    VARCHAR2(1)
 BOARD_ALLOY                                   VARCHAR2(1)
 BOARD_STEEL                                   VARCHAR2(1)
 BOARD_WEIGHT1                                 NUMBER
 BOARD_WEIGHT2                                 NUMBER
 BOARD_WEIGHT3                                 NUMBER
 BOARD_WEIGHT4                                 NUMBER
 GRADING_MACHINE                               VARCHAR2(1)
 NOTE                                          VARCHAR2(100)
 SOURCE                                        VARCHAR2(50)
```

CE_VESSEL_PRE_FP

```
 Name                             Null?    Type
 ----------------------------- -------- ------------------
--
 AREA                             NOT NULL VARCHAR2(1)
 VESSEL_NAME                      NOT NULL VARCHAR2(30)
 ID                               NOT NULL VARCHAR2(30)
 LICENCE_NO                                VARCHAR2(10)
 REG_NO                                    VARCHAR2(30)
 FROM_DATE                                 DATE
 TO_DATE                                   DATE
 YEAR                                      NUMBER(38)
 MONTH_FROM                                VARCHAR2(10)
 MONTH_TO                                  VARCHAR2(10)
 OWNER                                     VARCHAR2(30)
 SKIPPER                                   VARCHAR2(30)
 YRS_FISH_EXP                              NUMBER(38)
 FISH_DAYS                                 NUMBER(38)
 CREW_DAYS                                 NUMBER(38)
```

CLOSURE

```
 Name                             Null?    Type
 ----------------------------- -------- ------------------
--
 ID                               NOT NULL VARCHAR2(30)
 AREA                                      VARCHAR2(1)
 NAME                                      VARCHAR2(30)
 DESCRIPTION                               VARCHAR2(80)
 TYPE                                      VARCHAR2(30)
 STATUS                                    VARCHAR2(20)
 LINE_TYPE                                 VARCHAR2(30)
 DIRECTION                                 VARCHAR2(30)
 START_DATE                                DATE
 END_DATE                                  DATE
 FP                                        VARCHAR2(20)
 TRACK_GROUP                               VARCHAR2(20)
 NOTE                                      VARCHAR2(200)
```

CLOSURE_DETAIL

```
 Name                             Null?    Type
 ----------------------------- -------- ------------------
--
 ID                               NOT NULL VARCHAR2(30)
 SEQ_NO                           NOT NULL NUMBER(38)
 LAT_DEG                                   NUMBER(38)
 LAT_MIN                                   NUMBER(38)
 LAT_SEC                                   NUMBER(38)
 LONG_DEG                                  NUMBER(38)
 LONG_MIN                                  NUMBER(38)
 LONG_SEC                                  NUMBER(38)
 NOTE                                      VARCHAR2(200)
```

CMS Indexes

TABLE_NAME	*C*	*CONSTRAINT_NAME*	*col_name*	*STATUS*
CE_AUDIT_IMPORT	P	PK_AUD_IMP	ID	ENABLED
CE_CATCH_SHOT	P	PK_CE_SHOT	AREA	ENABLED
			BLOCK_NO	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
			SHOT	ENABLED
	R	FK_CE_FP	AREA	DISABLED
			FP	DISABLED
		FK_CE_SHOT_VES	AREA	DISABLED
			FP	DISABLED
			LICENCE_NO	DISABLED
CE_CATCH_SUM	P	PK_CE_CSUM	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LANDING_NO	ENABLED
			LICENCE_NO	ENABLED
	R	FK_CE_CSUM_FP	AREA	DISABLED
			FP	DISABLED
		FK_CE_CSUM_VES	AREA	DISABLED
			FP	DISABLED
			LICENCE_NO	DISABLED
CE_CATCH_SUM2	P	PK_CE_CSUM2	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
	R	FK_CE_CSUM2_FP	AREA	DISABLED
			FP	DISABLED
		FK_CE_CSUM2_VES	AREA	DISABLED
			FP	DISABLED
			LICENCE_NO	DISABLED
CE_CODES	P	PK_CE_COD	CODE	ENABLED
			CODE_GROUP	ENABLED

			CODE_USE	ENABLED
CF_COM	P	PK_COM	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
	R	FK_COM_FP	AREA	ENABLED
			FP	ENABLED
		FK_COM_VES	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_COM_BKT	P	PK_CF_COM_BKT	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
	R	FK_COM_BKT_FP	AREA	ENABLED
			FP	ENABLED
		FK_COM_BKT_VES	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_COM_BKT_DETAIL	P	PK_CF_COM_BKT_DET	AREA	ENABLED
			BUCKET_NO	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
			SHOT	ENABLED
	R	FK_COM_BKT_DET_COM_B	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_COM_DETAIL	P	PK_CF_COM_DET	DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
	R	FK_COM_DET_COM	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_COM_GRADE_GROU	P	PK_COM_GRA_GRP	NAME	ENABLED
CF_FP	P	PK_CF_FP	AREA	ENABLED
			FP	ENABLED
CF_GRADE	P	PK_CF_GRA	GRADE_ALT_NAME	ENABLED
CF_GRADE_SHOT	C	SYS_C0016588	AREA	ENABLED
		SYS_C0016589	FP	ENABLED
		SYS_C0016590	DAY	ENABLED
		SYS_C0016591	LICENCE_NO	ENABLED
		SYS_C0016592	GRADE	ENABLED
	P	PK_CF_GRA_SHO	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			GRADE	ENABLED
			LICENCE_NO	ENABLED
	R	FK_GRA_SHOLOG	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_IMP_LAND_DETAIL	P	PK_CF_LAN_DTL	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
			ORDER_NO	ENABLED
	R	FK_IMP_LANDTL_IMP_LAN	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_IMP_LAND_LOG	P	PK_CF_IMP_LAN_LOG	AREA	ENABLED

			LICENCE_NO	ENABLED
CE_IMP_SHOT	P	PK_CE_IMP_SHO	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
			SHOT	ENABLED
	R	FK_IMP_SHO_IMP_SHO_LO	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CE_IMP_SHOT_LOG	P	PK_CE_IMP_SHO_LOG	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CE_LAND_DETAIL	C	SYS_C0016618	AREA	ENABLED
		SYS_C0016619	FP	ENABLED
		SYS_C0016620	LICENCE_NO	ENABLED
	P	PK_LAN_DET	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
			ORDER_NO	ENABLED
	R	FK_LANLOG_DET	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CE_LAND_DETAIL_A2	P	PK_CE_LANDTL_A2	AREA	ENABLED
			DAY	ENABLED
			LICENCE_NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
	R	FK_LANDTL_A2_LANLOG_A2	AREA	ENABLED
			LICENCE_NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
CE_LAND_DETAIL_A3	P	PK_CE_LANDTL_A3	AREA	ENABLED
			DAY_NO	ENABLED
			LICENCE_NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
	R	FK_LANDTL_A3_LANLOG_A3	AREA	ENABLED
			LICENCE_NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
CE_LAND_DETAIL_A6B	P	PK_LAN_DET_A6B	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
			ORDER_NO	ENABLED
	R	FK_LANDET_A6B_LANLOG	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CE_LAND_DETAIL_A6E	P	PK_LAN_DET_A6E	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
			ORDER_NO	ENABLED
	R	FK_LANDET_A6E_LANLOG	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CE_LAND_LOG	C	SYS_C0016611	AREA	ENABLED
		SYS_C0016612	FP	ENABLED
		SYS_C0016613	LICENCE_NO	ENABLED
		SYS_C0016614	VESSEL_NAME	ENABLED
	P	PK_LAN_LOG	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED

	R	FK LANLOG FP	AREA	ENABLED
			FP	ENABLED
		FK LANLOG VES	AREA	ENABLED
			FP	ENABLED
			LICENCE NO	ENABLED
CF LAND LOG A2	P	PK LAN LOG A2	AREA	ENABLED
			LICENCE NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
CF LAND LOG A3	P	PK LAN LOG A3	AREA	ENABLED
			LICENCE NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
CF LAND LOG A6	P	PK LAN LOG A6	AREA	ENABLED
			FP	ENABLED
			LICENCE NO	ENABLED
	R	FK LANLOG A6 FP	AREA	ENABLED
			FP	ENABLED
		FK LANLOG A6 VES	AREA	ENABLED
			FP	ENABLED
			LICENCE NO	ENABLED
CF PRICE	P	PK CF PRI	BUYER	ENABLED
			PERIOD ID	ENABLED
CF PRICE DETAIL	P	PK CF PRI DET	BUYER	ENABLED
			GRADE	ENABLED
			PERIOD ID	ENABLED
	R	FK PRI DET PRI	BUYER	ENABLED
			PERIOD ID	ENABLED
CF RECORD	P	PK CF REC	AREA	ENABLED
			FP	ENABLED
CF RECORD DETAIL	P	PK CF REC DET	AREA	ENABLED
			FP	ENABLED
			LICENCE NO	ENABLED
	R	FK REC DET REC	AREA	ENABLED
			FP	ENABLED
CF SHOT	C	SYS C0016597	AREA	ENABLED
		SYS C0016598	FP	ENABLED
		SYS C0016599	DAY	ENABLED
		SYS C0016600	LICENCE NO	ENABLED
		SYS C0016601	SHOT	ENABLED
		SYS C0016602	BLOCK NO1	ENABLED
	P	PK CF SHO	AREA	ENABLED
			BLOCK NO1	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE NO	ENABLED
			SHOT	ENABLED
	R	FK SHO SHOLOG	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE NO	ENABLED
CF SHOT A10	P	PK CF SHO A10	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE NO	ENABLED
			SHOT	ENABLED
	R	FK SHO A10 SHOLOG	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED

CF_SHOT_A4	P	PK_CF_SHO_A4	AREA	ENABLED
			DAY_NO	ENABLED
			LICENCE_NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
	R	FK_SHO_A4_SHOLOG_A4	AREA	ENABLED
			LICENCE_NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
CF_SHOT_A8	P	PK_CF_SHO_A8	AREA	ENABLED
			BLOCK_NO1	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
			SHOT	ENABLED
	R	FK_SHO_A8_SHOLOG	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_SHOT_LOG	C	SYS_C0016573	AREA	ENABLED
		SYS_C0016574	FP	ENABLED
		SYS_C0016575	DAY	ENABLED
		SYS_C0016576	LICENCE_NO	ENABLED
		SYS_C0016577	VESSEL_NAME	ENABLED
	P	PK_CF_SHO_LOG	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
	R	FK_SHOLOG_FP	AREA	ENABLED
			FP	ENABLED
		FK_SHOLOG_VES	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_SHOT_LOG_A4	P	PK_SHOLOG_A4	AREA	ENABLED
			LICENCE_NO	ENABLED
			MONTH	ENABLED
			YEAR	ENABLED
CF_SHOT_LOG_DETAIL	P	PK_CF_SHO_LOG_DET	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
	R	FK_SHOLOG_DET	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_TAG_A8	P	PK_CF_TAG_A8	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
	R	FK_TAG_DETA8_SHOT_LOG	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
CF_TAG_DETAIL_A8	P	PK_CF_TAG_DET_A8	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			ID	ENABLED
			LICENCE_NO	ENABLED
	R	FK_TAG_DET_TAG_A8	AREA	ENABLED
			DAY	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED

CE_VESSEL	P	PK_CE_VES	AREA	ENABLED
			FP	ENABLED
			LICENCE_NO	ENABLED
	R	FK_VES_FP	AREA	ENABLED
			FP	ENABLED
CE_VESSEL_EQUIP	P	PK_CE_VES_EQUIP	AREA	ENABLED
			LICENCE_NO	ENABLED
			START_DATE	ENABLED
CE_VESSEL_EQUIP_OLD	P	PK_CE_VES_EQUIP_OLD	AREA	ENABLED
			LICENCE_NO	ENABLED
			START_DATE	ENABLED
CE_VESSEL_PRE_FP	P	PK_CE_VES_PRE_FP	AREA	ENABLED
			ID	ENABLED
			VESSEL_NAME	ENABLED
CLOSURE	P	PK_CLO	ID	ENABLED
CLOSURE_DETAIL	P	PK_CLO_DET	ID	ENABLED
			SEQ_NO	ENABLED
	R	FK_CLO_CLO_DET	ID	ENABLED

Forms

Listing of CMS forms and their purpose

Fishing Periods	Fishing Periods	Ce_fp

This screen is used to record uniquely identified fishing periods. Their may be typically be 6 per year.

Vessels	Vessels	ce_vessels

Used to record the vessels active within a specified fishing period. Also recorded for each vessel (for the fishing period) are:

- Skipper
- Owner
- Years Fishing
- Fishing Days
- Crew Days

Vessels (old)	Vessels (old)	ce_vessel_pre_fp

Used to record a master list of vessels active prior to the introduction of fishing periods.

Commercial Grades	Commercial Grades	ce_grade

Used to record the various commercial grades.

The column “Grade” is intended as the “display” name for the grade ie to be used in printed output. It can be exactly the same as the Grade Alt Name if preferred but is intended as a way of providing a standard name in output when grades have alternate spelling but really mean the same.

The “Grade Alt Name” is intended as the uniquely identifying grade name, typically the grade name traditionally used.

The checkbox “Speed up data entry”, when checked by the user, assists with automatic creation of some fields when entering new rows of data in the following way. This was mostly intended for use by the developer when setting up the original data set.

- After entering a value in Grade Alt Name (and moving the cursor from that column) Grade is automatically set to the value of Grade Alt Name.
- After entering a HI (high) value, a suitable Grade Alt Name and Grade name are automatically created.

Commercial Prices	Commercial Prices	ce_price

Used to store commercial prices.

Landing Logbook A1	Landing Logbook A1	ce_land_log

Used to store the main landing Logbook data ie from the most recently used version of the logbook form. (A1 through to A10 refer to a simple set of codes used by the developer to distinguish between the many paper forms).

Daily Log (A9 & A5)	Daily Log (A9 & A5)	ce_daily_log

Used to store the main landing Daily Logbook data ie from the most recently used version of the daily logbook form.

Vessel Equipment (current)	Vessel Equipment (current)	ce_vessel_equip

Intended to record current details of ship and equipment configuration on each vessel.

Vessel Equipment (87/88 – 2002)	Vessel Equipment (87/88 – 2002)	ce_vessel_equip_old

Intended to record historical details of ship and equipment configuration on each vessel.

Vessel calculations	Vessel calculations	ce_vessel_calc

Intended to record details of calculations performed on ship and equipment.

Prawn daily and Monthly Logbook Statistics (1978) A4	Prawn daily and Monthly Logbook Statistics (1978) A4	ce_daily_log_a4

Used to store Logbook data form the appropriate paper form.

Used to store Logbook data form the appropriate paper form.

Daily Log Shot Sheet (No Tide/Trawled) A7 runs A8	Daily Log Shot Sheet (No Tide/Trawled) A7 runs A8	ce_ daily_log_a8

Used to store Logbook data form the appropriate paper form.

Used to store Logbook data form the appropriate paper form.

Month Log A2 (1985)	Month Log A2 (1985)	ce_land_log_a2

Used to store Logbook data form the appropriate paper form.

Prawn Daily Logbook Statistics (1978) A3	Prawn Daily Logbook Statistics (1978) A3	ce_ land_log_a3

Used to store Logbook data form the appropriate paper form.

Prawn Unloading Record Sheet A6	Prawn Unloading Record Sheet A6	ce_ land_log_a6

Used to store Logbook data form the appropriate paper form.

Record Sheet (Daily & Monthly)	Record Sheet (Daily & Monthly)	ce_record

Used to store Logbook data form the appropriate paper form.

Commercial Catch Data	Commercial Catch	ce_com

	Data	

Records commercial catch data.

Note that 2 rows of headings are dynamic. These rows are just above the data rows that occupy the lower half of the screen. The 2 rows of headings display the grades and their carton weight (when cartons ie not Kg are used as entry units). Note that Cartons or Kg can be selected in a field in the top half of the screen in a dropdown list labelled “Ctn or Kg”.

The first heading row, of grades, can be most easily reset using the buttons provided as detailed below. The second heading row, of carton weights, will retain any values, once entered. If the settings are all zero/blank then the values will be automatically reset to the value in Carton Weight1 once this is entered. Values can be reset to blank with the button provided (see below).
Buttons available are:

1. “View preset Grades” – Displays a list of preset grade groups, one of which can be selected into the grade heading fields just above the data entry fields in the lower half of the screen. These groups are edited in a screen called Commercial Grade Groups.
2. “Preset Grades” - resets the headings to the default set nominated in the Commercial Grade Groups screen.
3. “Edit Grade Groups” – calls up the Commercial Grade Groups screen.
4. “Zero Wt Headings” – sets the carton weights under each grade heading to zero.

Commercial Buckets	Commercial Buckets	ce_com_bkt

Used to store commercial bucket data.

Frequency Distribution	Frequency Distribution	ce_com_freq

Used to store size frequency distribution information.

Commercial Grade Groups	Commercial Grade Groups	ce_com_grade_group

Used to store commercial grade groupings. These are used in the Commercial Catch Data screen.

dBase data	dBase data	ce_orig_dbase_data

Used to review some historical data that came from a dBase application.

Bad data from dBase	Bad data from dBase	ce_ba_dbase_data

Used to review a small set of data in the dBase data that needs to be cleaned up before use.

Dataflex Com data	Dataflex Com data	ce_load_prcom_dataflex

Used to review some historical data that came from a Dataflex application.

Load SARDI data	Load SARDI data	ce_sardi_load

A generic and prototype screen intended to eventually load incoming data from SARDI.

View SARDI Daily Log data	View SARDI Daily Log data	ce_sardi_daily

A generic and prototype screen intended to eventually preview incoming data from SARDI.

View SARDI Landing Logbook data	View SARDI Landing Logbook data	ce_sardi_land

A generic and prototype screen intended to eventually preview incoming data from SARDI.

Closures	Closures	ce_closure

A prototype screen to demonstrate how closure data might be stored.

Database Operation Help

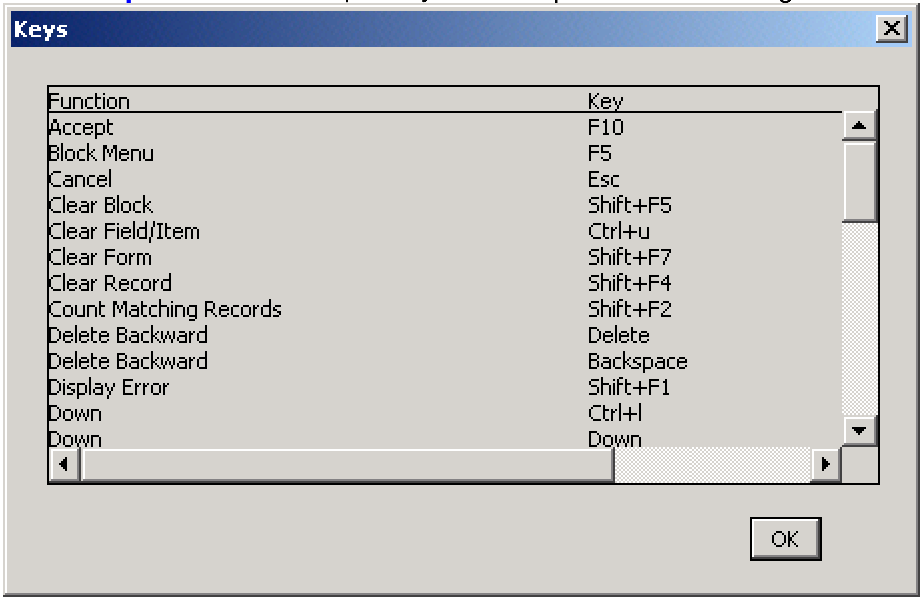
Oracle Hot Keys

You can use the following shortcut keys in Oracle data entry screens.

F3 Duplicate just the field in the preceding record
Use this when inserting new records (ie Insert Record first)
F4 Duplicate the record (row) immediately above the current record
Use this when inserting new records (ie Insert Record first)
F7 Enter a query (press F7 then enter search criteria in one or more data entry fields)
F8 Execute the query (Tip: just press F8 to requery all data)
F9 Display List of Values (only available in a field where "List of Values" displays at the bottom of the screen when a field is selected)
F10 Save changes

Others are available.

☞ **Tip:** Use the Help – Keys menu option to see a longer list of keys, for example…



Oracle Form Query tricks

Count Query Hits

The menu option *Count Query Hits* found under the menu *Query* option will tell you how many records fit your query criteria. If you enter no query criteria then it will tell you how many records in total are in the underlying Oracle table, which is sometimes useful

Oracle is case sensitive

Remember that Oracle is case sensitive. Entering search criteria of "BOOBOOK" will fail to find "boobook" in the database. Many fields only allow data to be entered as upper case to reduce this problem.

Wildcard (%) Queries

Wildcard queries are possible with the “%” character.

To search for all vessels starting with ‘A’, start a query (eg use F7 or menu) then enter “A%” in the vessel field, then execute the query (eg F8).

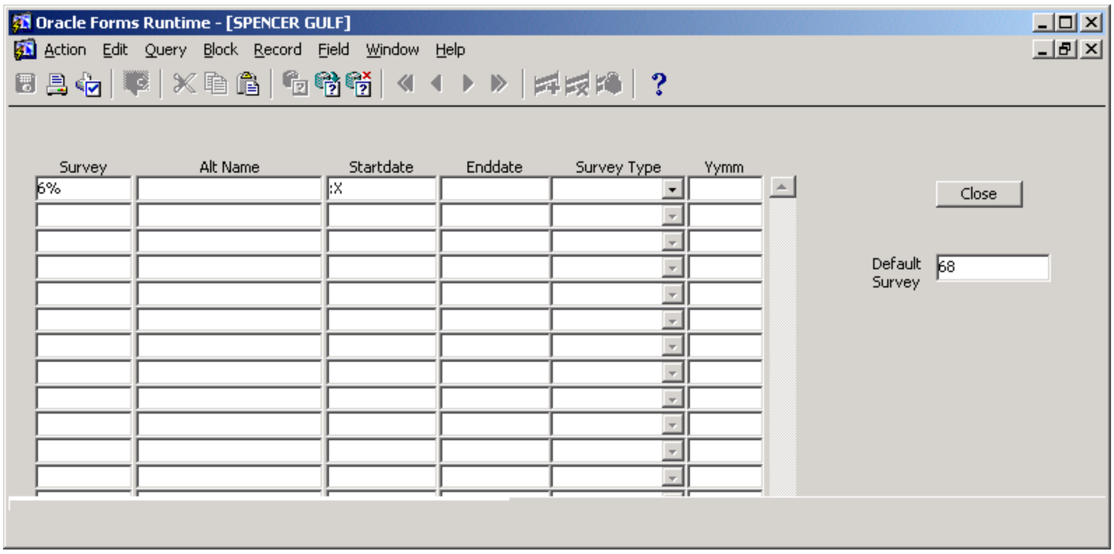
To find all dates with a month starting with ‘J’ (when displayed in form ’01-JUN-1998’), enter “%J%” in the relevant date field..

To find all surveys ending in “1”, enter “%1”.

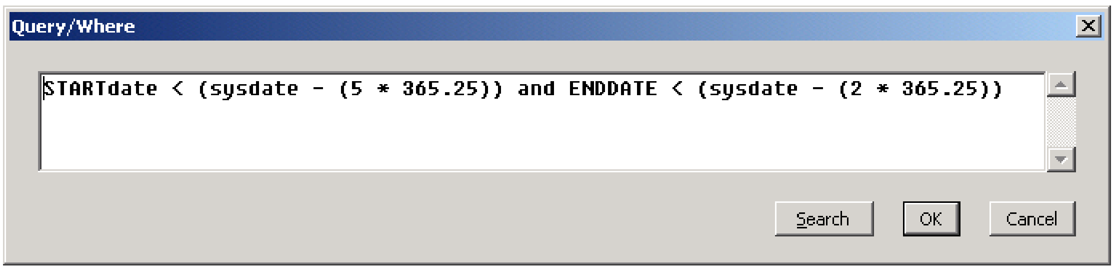
Advanced queries using :x syntax

Advanced SQL queries in Oracle Forms are possible by entering a value like “**:x**” in a field when defining a query.
The query shown below sets up a query looking

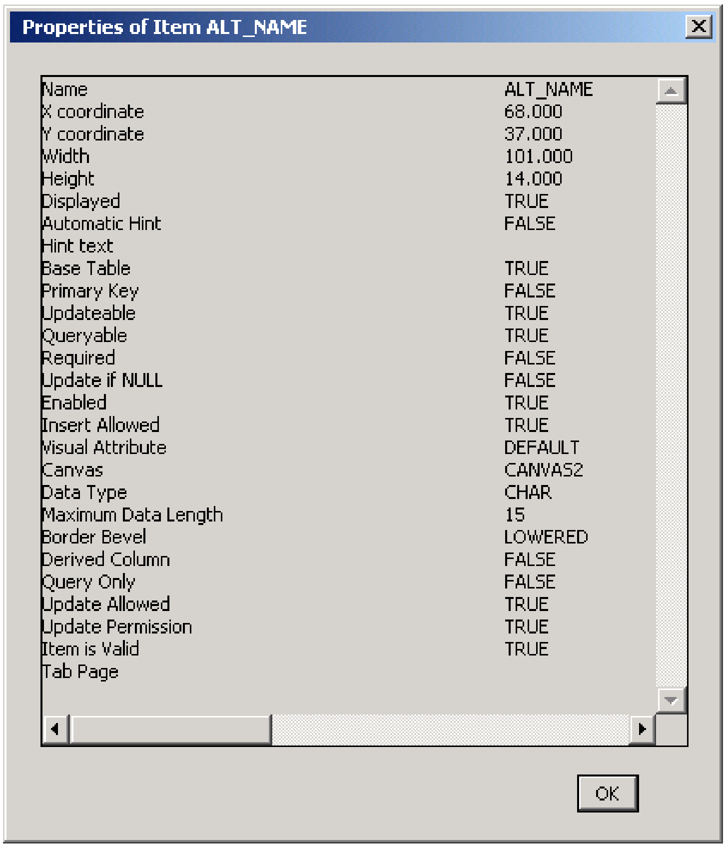
1. initially for all surveys starting with a 6
2. and also that meet the criteria for “STARTDATE” to be further defined in the screen which displays after you select “EXECUTE QUERY” eg with button F8. See the second screen shot below.



The next screen appears after you select Execute Query. Enter any valid SQL referencing the field name(s) in the underlying Oracle table.



You must understand at least basic SQL to do this and also know the field names in the underlying table. To see the field names, before entering query mode, place the cursor in a field and press key F1.



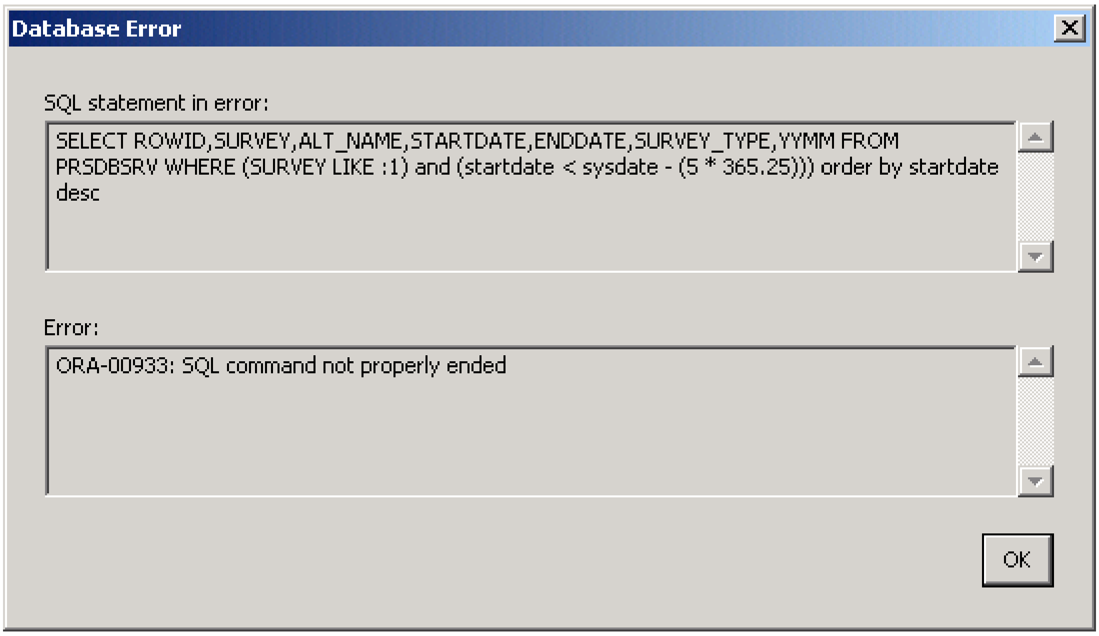
Note that the Properties page displayed shows the field name both in the top screen title and in the first row of properties.

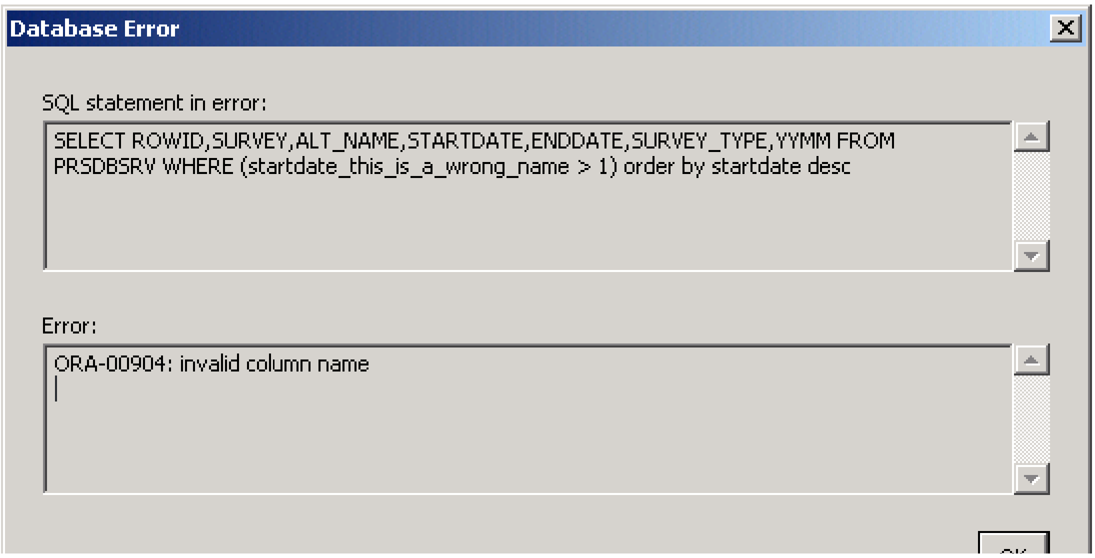
See also screen and table documentaton later in this document.

If you make a SQL syntax error then the only response is a message: FRM40505: ORACLE error: unable to perform query

However if you select Help -> Display Error from the Menu at the top of the screen then you can see the complete SQL that is created and that fails (see next 2 examples).

In more complex cases more information may be required. One method is to cut and paste the “SQL statement in error” to a SQL*Plus session and edit and run it there. References to items like “:1” need to be edited in SQL*Plus (here “:1” translates as “6%”. Note that reasonable command of SQL*Plus is required.





Printing and Saving Screen Shots

You can print out the visible screen image using:

Hot Key:	Shift + F8
Menu:	File -> Print
Icon:	Printer icon near top left of screen

You can save the visible screen image by using Alt + PrntScrn to copy the current visible screen to the clipboard then pasting that to a program like Microsoft Word and saving that Word file.

Note that if a screen is not fully visible then the data not visible cannot be printed or saved as a screen image this way. The data is of course in the database, and viewable by scrolling the screen.

To print out more data than can fit is a single screen image either:

1. increase the screen resolution (text size may be too small then)
2. run an existing report, write a new one using SQL or Oracle Reports or see if an exiting report can output the data in ascii format, then load it into Excel for customized reporting.

*Oracle SQL*Plus Notes*

Oracle's data language is PL/SQL (Procedural Language/Structured Query Language). This used whenever interacting with the database through tools like ODBC, Oracle Forms, Reports and Graphs or SQL*Plus (the tool that allows plain PL/SQL use.)

The main 2 references for version 8i held on CD are the SQL and the PL/SQL Reference.

- **Oracle8*i* Server and SQL*Plus**
  Includes SQL Reference, Administrator's Guide, Error Messages, Tuning, Backup and Recovery, Replication, Data Warehousing

- **Oracle8*i* Server Application Development**
  *Includes PL/SQL, Application Developer's Guide, XML, LOBs, Advanced Queuing, OCI, Pro*C/C++*

Further references to SQL*Plus are also available.

SQL*Plus

SQL*Plus User's Guide and Reference	**HTML PDF**
SQL*Plus Quick Reference	**HTML PDF**
SQL*Plus Accessibility Guide for Windows	**HTML PDF**

Basic Survival Notes

Always check what user you are logged on as. Otherwise you could be viewing the wrong data.

Be aware that there is absolutely nothing to stop you updating or deleting data when in SQL*Plus.

NEVER, EVER USE THE COMMANDS DELETE or UPDATE unless you know precisely what you are doing.

However if you stick to SELECT commands then you are only ever reading data and never changing data and therefore safe.

You must fully understand the Oracle data structure to achieve the correct results.

Basic SELECT syntax is

select col1, col2, col3
from table1, table2
where <criteria1>
and <criteria2>
order by col4, col4;

Eg

```
select log.survey, log.region, log.area, log.station, vessel, samsize
from   prsdblog log,
       prsdbsam sam
where  log.station = sam.station
and    log.area    = sam.area
and    log.region  = sam.region
and    log.survey  = sam.survey
and    log.survey  = '68'
and    samsize     >= 32
order by log.survey, log.region, log.area, log.station, vessel;
```

Useful commands include:

Spool survey_68_version3.txt [write all following output to a file]
Spool off [close spool file]

Host [exit to MS-DOS to see current directory]

Set linesize 132 [sets width of output lines]
Set pagesize 999 [sets log pagelenth ie headings appeare every 999 lines]
Set pagesize 0 [sets headings off]

To edit a file use

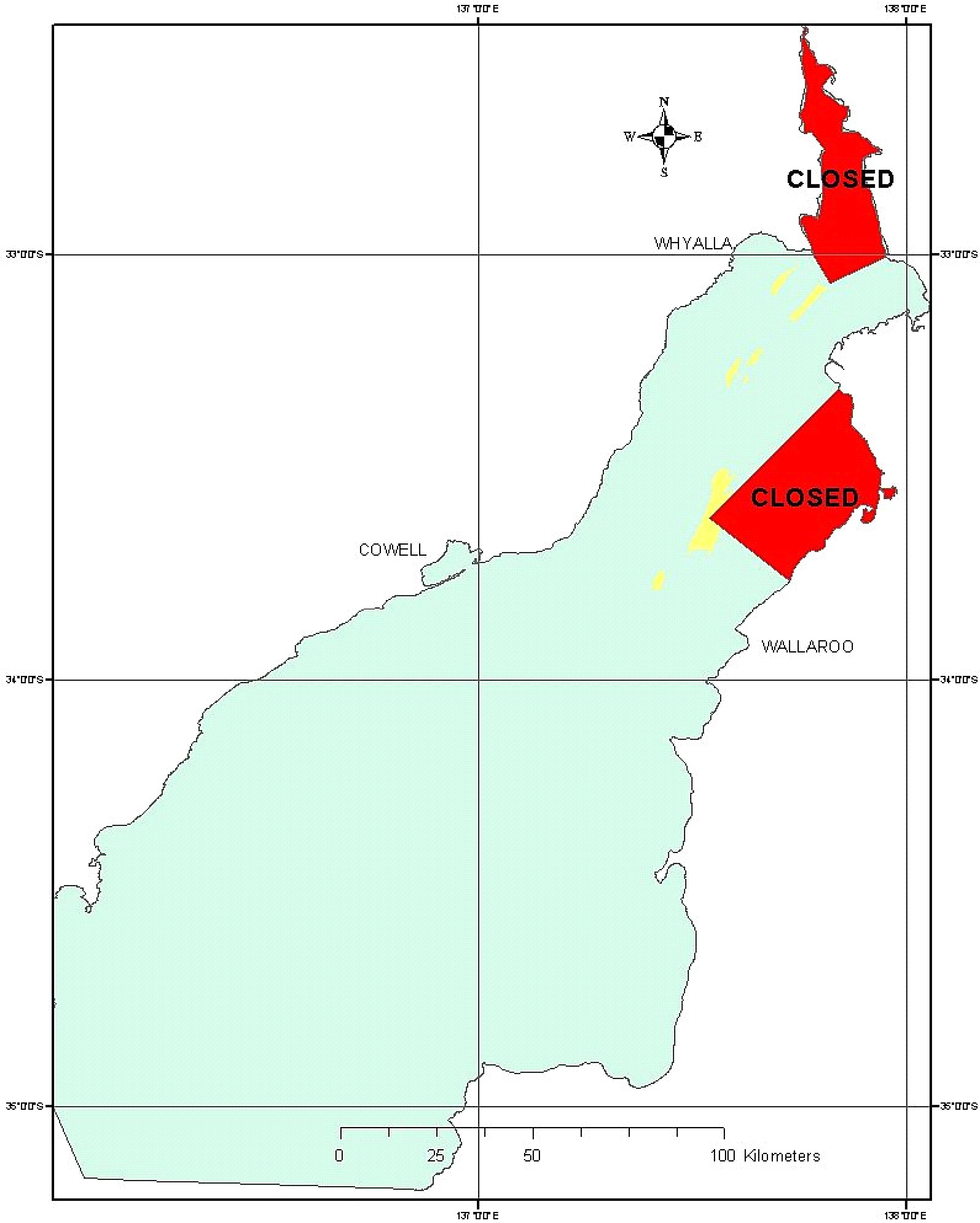
Ed query1_prs_olddata [assumes files is called query1_prs_olddata and is current SQL*Plus working directory]

To run a saved query file

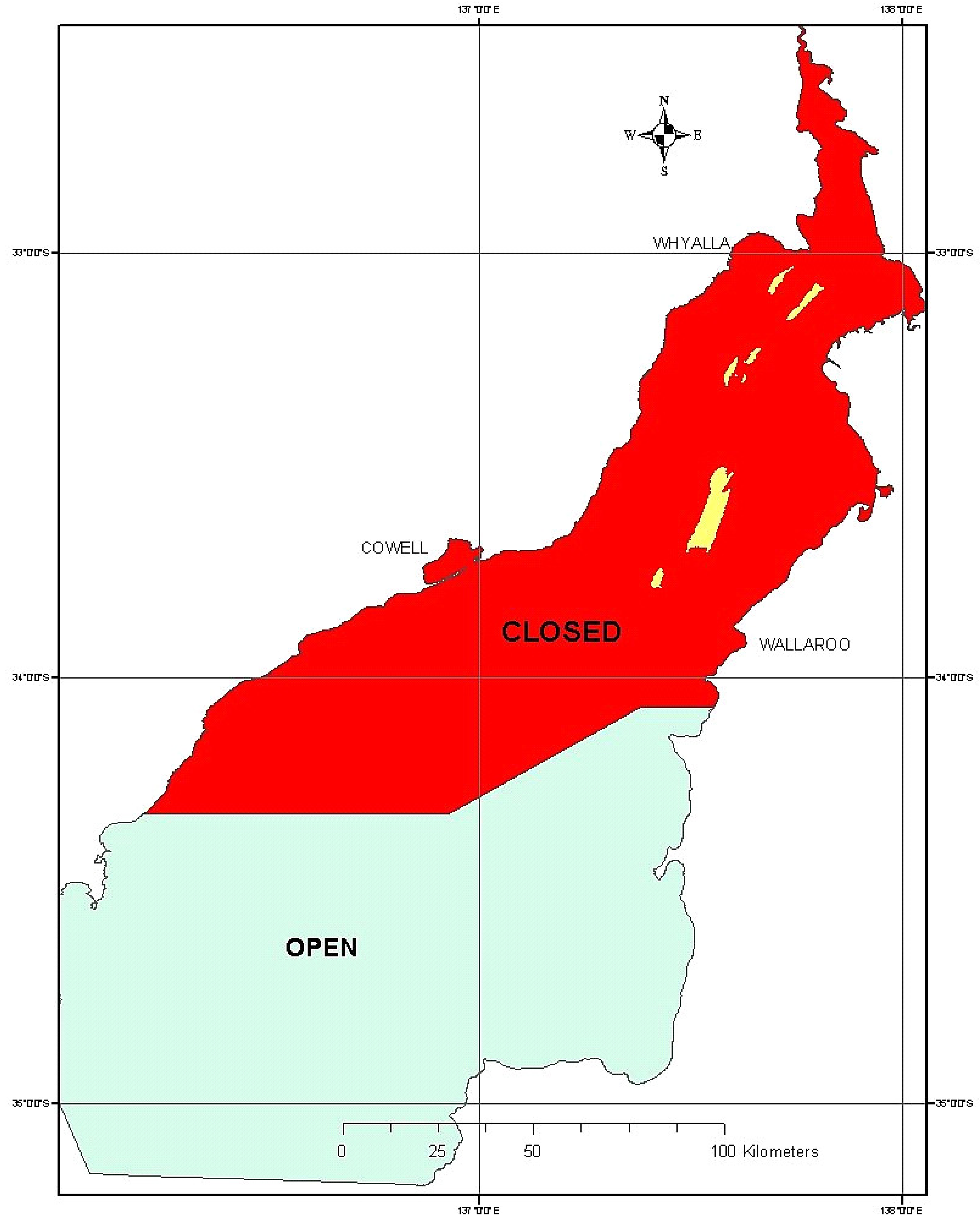
@query1_prs_olddata

Appendix 6: Trawling areas in Spencer Gulf.

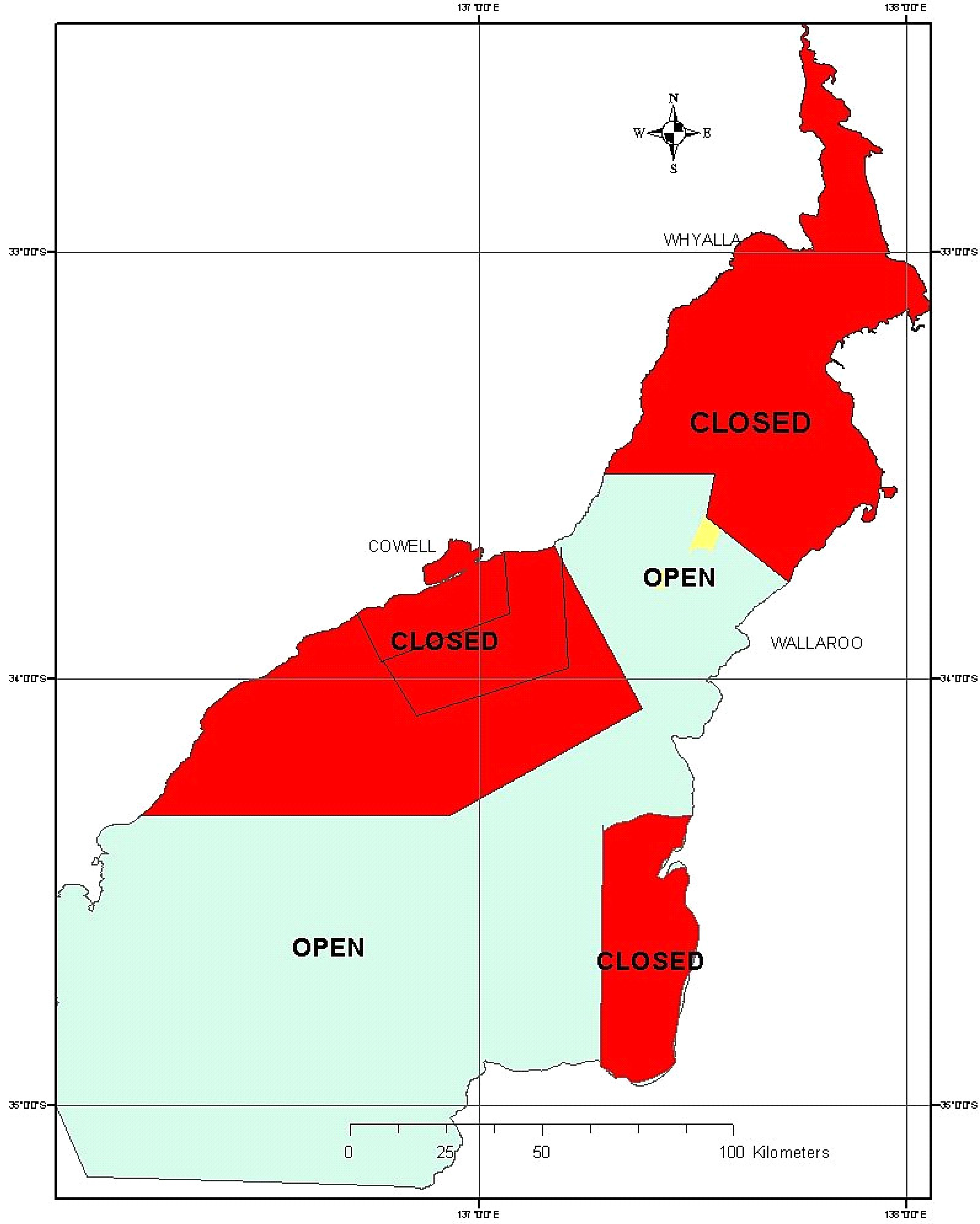
Permanent closed areas



Main southern area closure, March to April, Spencer Gulf



Main spatio-temporal closures April to June & November to December, Spencer Gulf.



Appendix 7: ANOVA results of prawn recruitment, egg production and spawners at Venus Bay

Appendix 7a: Mean number (square root transformed) of prawn recruits (males <33, females <35 mm CL) over Year (1991-1997), Zone (inshore, mid-shore and off-shore) and Line (alongshore).

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Plot stratum	1	42.833	42.883	7.27	
Plot.units stratum	1				
Year	6	1171.461	195.243	33.11	<0.001
Zone	2	194.890	97.445	16.53	<0.001
Line	2	51.347	25.673	4.35	0.017
Year.Zone	12	375.869	31.322	5.31	<0.001
Year.Line	12	350.569	29.214	4.95	<0.001
Zone.Line	4	43.475	10.869	1.84	0.132
Year.Zone.Line	24	251.067	10.461	1.77	0.037
Residual	62	365.578	5.896		
Total	125	2847.139			

Appendix 7b: Mean number (square root transformed) of prawn recruits (males <33, females <35 mm CL) over Year (1991-1997), Zone (inshore, mid-shore and off-shore) with Line (alongshore) nested in Zone.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Plot stratum	1	42.833	42.883	7.27	
Plot.units stratum					
Year	6	1171.461	195.243	33.11	<0.001
Zone	2	194.890	97.445	16.53	<0.001
Year.Zone	12	375.869	31.322	5.31	<0.001
Zone.Line	6	94.822	15.804	2.68	0.002
Year.Zone.Line	36	601.636	16.712	2.83	<0.001
Residual	62	365.578	5.896		
Total	125	2847.139			

Appendix 7c: Mean number (square root transformed) of prawn recruits (males <35, females <40 mm CL) over Year (1991-1997), Zone (inshore, mid-shore and off-shore) with Line (alongshore) nested in Zone.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Plot stratum	1	67.77	67.77	6.67	
Plot.units stratum					
Year	6	2882.83	480.47	47.26	<0.001
Zone	2	185.80	92.900	9.14	<0.001
Year.Zone	12	718.47	59.87	5.89	<0.001
Zone.Line	6	216.49	36.08	3.55	0.004
Year.Zone.Line	36	936.90	26.03	2.56	<0.001
Residual	62	630.35	10.17		
Total	125	5638.61			

Appendix 7d: Mean egg production (square root transformed) over Year (1991-1997), Zone (inshore, mid-shore and off-shore) with Line (alongshore) nested in Zone.

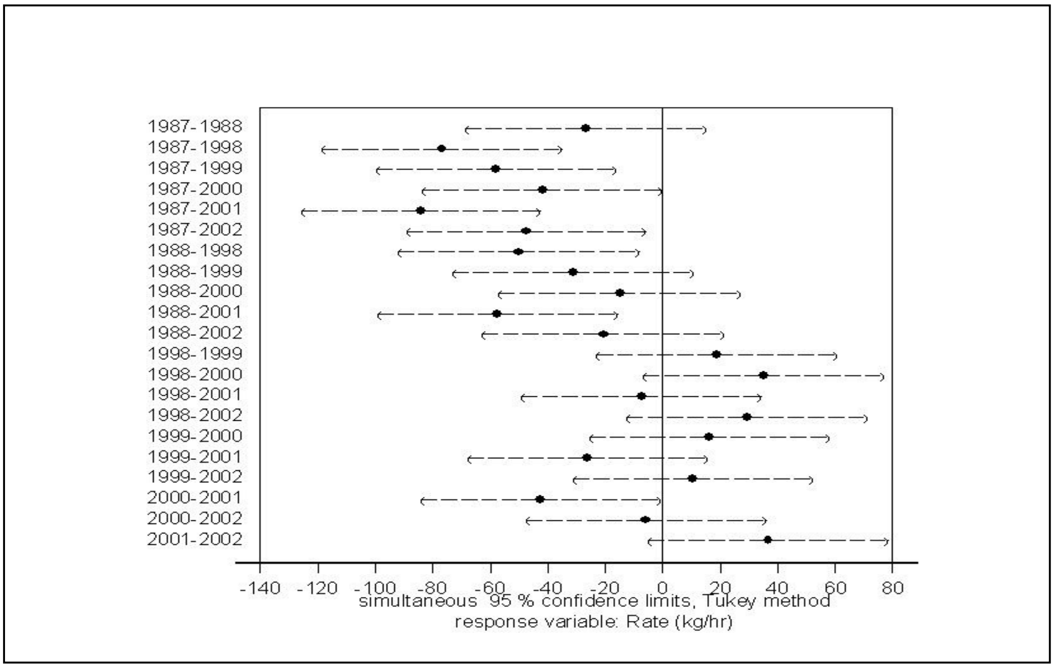
Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Plot stratum	1	16.772	16.772	7.74	
Plot.units stratum					
Year	6	2420.462	403.410	186.18	<0.001
Zone	2	6.760	3.380	1.56	0.218
Year.Zone	12	275.452	22.954	10.59	<0.001
Zone.Line	6	120.464	20.077	9.270	<0.001
Year.Zone.Line	36	274.202	7.617	3.520	<0.001
Residual	62	134.344	2.167		
Total	125	3248.457			

Appendix 7e: Mean female spawners (>42 mm CL) over Year (1991-1997), Zone (inshore, mid-shore and off-shore) with Line (alongshore) nested in Zone.

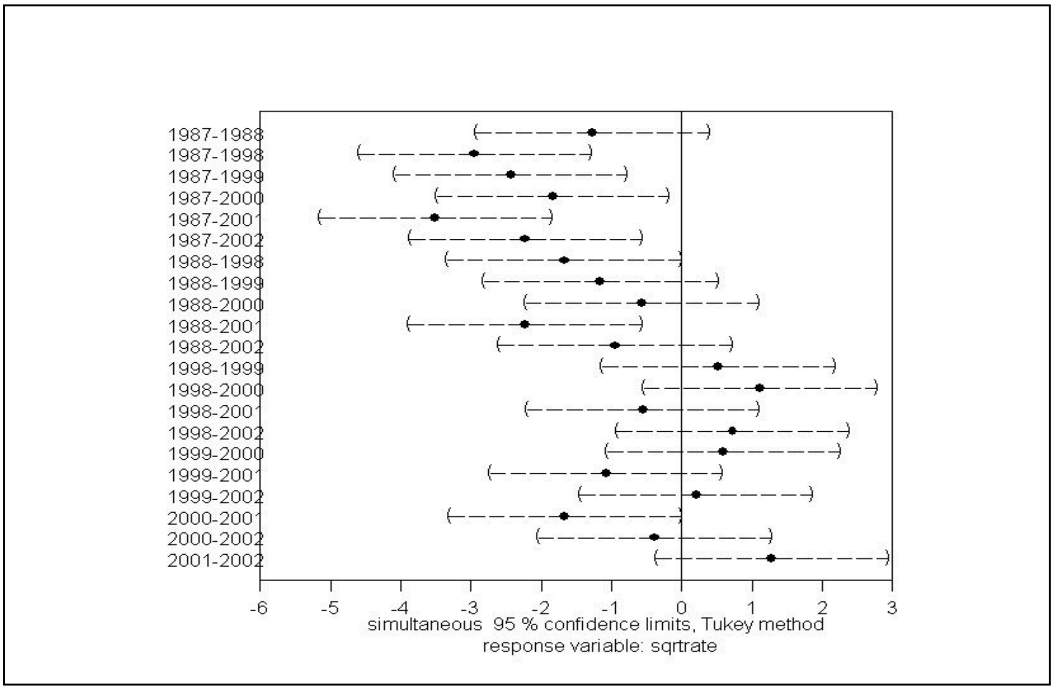
Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Plot stratum	1	20.778	20.778	5.19	
Plot.units stratum					
Year	6	4784.639	797.440	199.180	<0.001
Zone	2	31.255	15.628	3.900	0.025
Year.Zone	12	502.344	41.862	10.460	<0.001
Zone.Line	6	224.233	37.372	9.33	<0.001
Year.Zone.Line	36	455.359	12.649	3.160	<0.001
Residual	62	248.219	4.004		
Total	125	6266.828			

Appendix 8: Results of multiple comparison test of mean biomass density time series

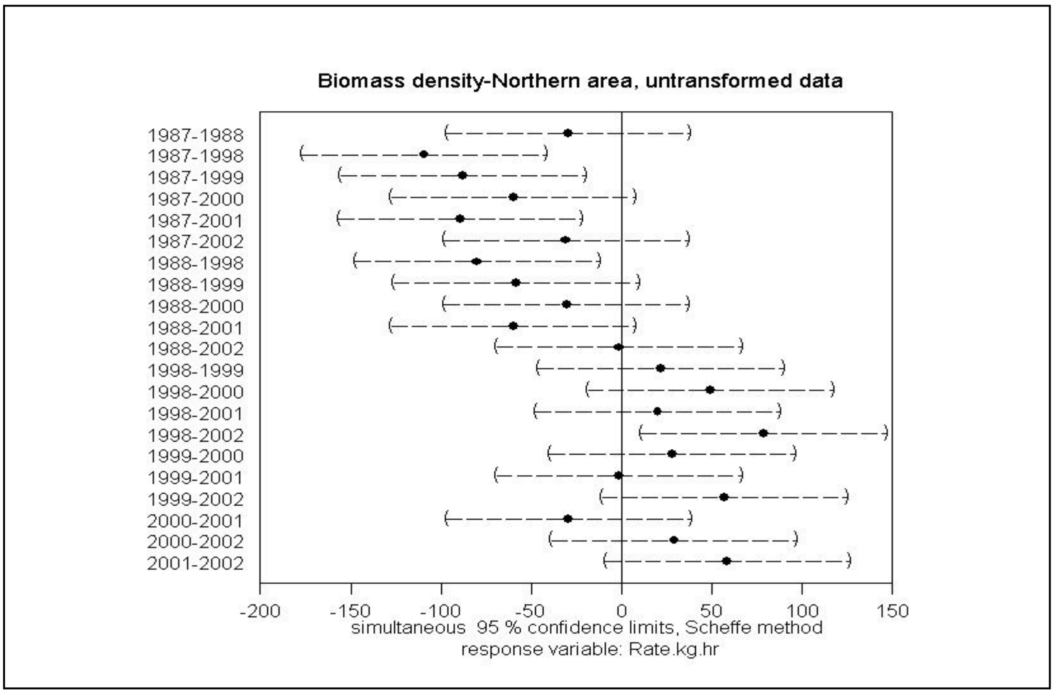
Appendix 8a: Tukey multiple comparison test of mean biomass density (kg/h) over all regions in Spencer Gulf, 1987 & 1988 and 1998-2002. Data untransformed.



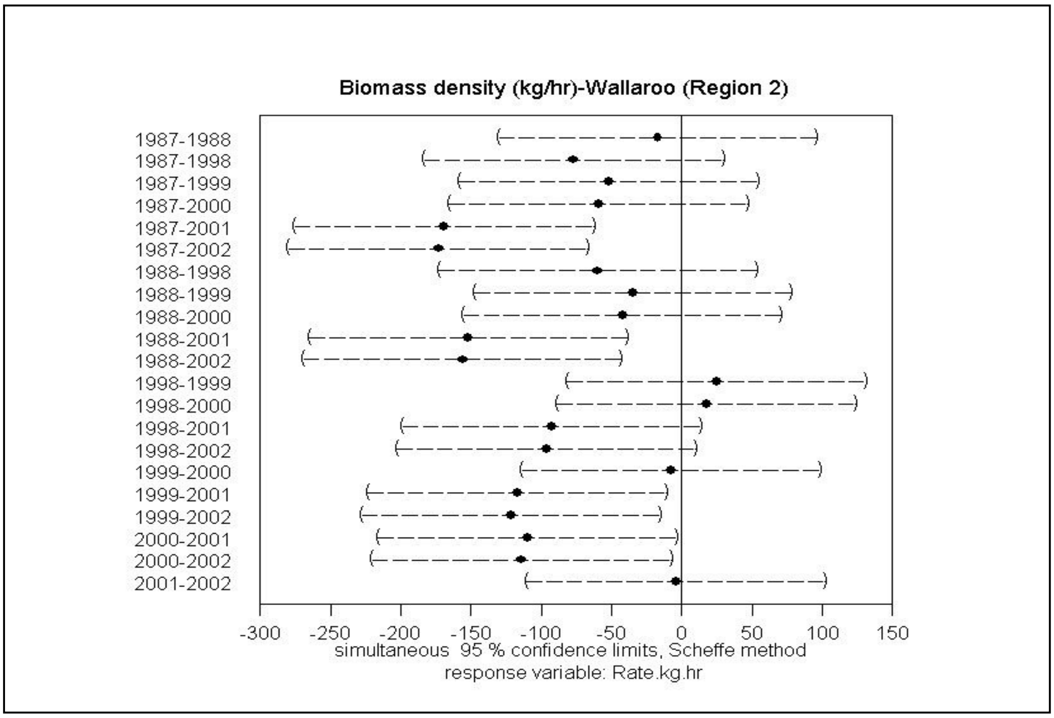
Appendix 8b: Tukey multiple comparison test of square root transformed mean biomass density (kg/h) over all regions in Spencer Gulf, 1987 & 1988 and 1998-2002.



Appendix 8c: Scheffe multiple comparisons of mean annual biomass density (kg/h) for the Northern region (Region 1), Spencer Gulf.



Appendix 8d: Scheffe multiple comparisons of mean annual biomass density (kg/h) for the Wallaroo region (Region 2), Spencer Gulf.



Appendix 8e: Scheffe multiple comparisons of mean annual biomass density (kg/h) for the Gutter region (Region 3), Spencer Gulf.