FISHERY ASSESSMENT REPORT
DPI AGENCY FOR FOOD AND FIBRE SCIENCES

THE QUEENSLAND STOUT WHITING FISHERY 1991 TO 2002

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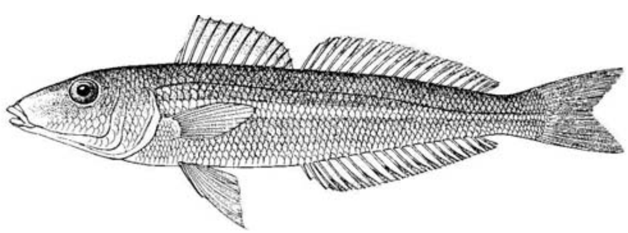
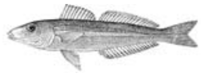


MARCH 2002

Queensland Government
Department of Primary Industries
Southern Fisheries Centre
Deception Bay



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1. EXECUTIVE SUMMARY

The stout whiting (*Sillago robusta*) fishery in southern Queensland is restricted to offshore waters between Caloundra and Sandy Cape in depths ranging between 20 and 50 fathoms. The fishery consists of five licensed trawlers (T4 endorsement). The fishery is managed by means of a 'industry agreed' yearly Total Allowable Catch (TAC), which is reviewed annually and divided equally among the vessels. The TAC quota was set at 1000 tonnes for the managed area in 2002.

The stout whiting resource was assessed using a newly developed age-structured model, along side with the previous virtual population and surplus production models. The new model was tuned simultaneously to standardised monthly-catch-rates and yearly patterns in the stout whiting catch age-structure. The limit reference point B/K (the ratio of exploitable biomass in 2002 to the exploitable component of the virgin carrying capacity) was estimated to be at about 0.19 (B/K less than 0.2 is generally accepted as high risk of over exploitation). The results from all three models should be viewed cautiously as their uncertainty is high. Given the high uncertainty, any increase in TAC above 1000 t has high risk. In the last four years total catch has varied between 1178 t and 498 t. This year's assessment has shown no increase in recruitment and biomass after the catch levels of 881 t in 2000 and 855 t in 2002. The management strategy evaluation suggests this years TAC should range between 700t and 900t depending on the target management objectives of risk and yield from the fishery (Table 3.6). This Table 3.6 should be used to guide the decision on TAC setting and to understand how best to compromise the issues of risk (over fishing) and optimising yield (maximising catch and value in the fishery). Summary of the assessment is given in Table 1.1

Table 1.1 Summary of fishery assessment and suggested TACs.

Summary	**1999**	**2000**	**2001**	**2002**
Voluntary TAC	1400 t	1000 t	1000 t	1000 t
Total catch	1178 t	498 t	881 t	855 t
T4 observed CPUE (kg/boat/hour)	141	113	156	165
Percent catch of 0+ aged fish	7%	16%	19%	5%
2002 Management Parameters				
Ratio of current biomass to carrying capacity (B/K)	-	0.259	0.366 and 0.239	0.19 and 0.44
Age-structured model $TAC_{3/4MSY}$	-	-	-	793 (375:1738)
VPA $TAC_{0.1}$ (95% CI in parentheses)	-	1050 (690:1857)	929 (542:2140)	869 (546:2221)
SPM $TAC_{0.1}$ (95% CI in parentheses)		575 (1:1507)	898 (711:1505)	720 (295:1944)

2. INTRODUCTION

2.1 Main features of the 2002 fishery

Target catch composition:	Stout whiting, *Sillago robusta*; fish mostly 15-20 cm, up to 23 cm FL
Annual catch and effort	2002: 855 t from 5174 hours effort; observed CPUE 165 kg/hr
Value:	$2.7m, all export to Asia, Japan and Taiwan
Fleet:	5 vessels
Location:	south-east Queensland; restricted area between the 20 and 50 fathom contours between Sandy Cape and Caloundra
Fishing Method:	vessels < 20m; single otter gear; net size 33 m; mesh size 55 mm; sweep length 90 m
Permitted By-product:	red spot whiting, yellowtail scad, goatfish, pinkies, octopus, cuttlefish, Balmain bugs, bugs and prawns
Discards:	whiptails, squid, prawns and Moreton bay bugs
Management	2002: total allowable catch (TAC) 1000 t; seasonal closure between 1 January and 31 March; Prawn trawl (T1) southern closure between 20 September and 1 November
Stock Assessment:	annual; Monthly age-structured model, Virtual Population Analysis (VPA), surplus production model.

2.2 History

The whiting fishery started in 1981 on the south coast of Queensland with one operator fishing for red spot whiting (*Sillago flindersi)* and progressively moved to target stout whiting (*Sillago robusta)* as exploration of new grounds provided evidence that a commercial fishery existed for this species. The two species (stout and red spot whiting) have overlapping distributions where both species can be found.

The fish were marketed at a relatively stable price of $1.80/kg when the fishery commenced. To capitalise on demand two more boats entered the fishery. The product was sorted in a land-based factory, and sold in 10kg layered, frozen packs. Market demand increased and by 1984 up to 1000kg per day of stout whiting was being taken as by-catch by prawn trawlers. As by-catch the quality of this product did not satisfy market standards and about this time Thailand entered the market with a lower priced product which saw participation in this fishery shrink to the one original operator.

This single operator continued in the fishery and up-graded equipment and fishing practice. This included large freezer and "snap" capacity and the specialised hopper and conveyor equipment for at-sea sorting of the catch that is a feature of the fishery today.

A stout whiting trawler

The fishery underwent rapid expansion between 1989 and 1990 with more than 10 boats reported as being involved, landing a 1990 catch of 1789 tonne of stout whiting. The fishery was restructured in 1991 as a limited entry developmental fish-trawling fishery in the area between 20 and 50 fathoms between Caloundra and

Sandy Cape. The fishery operated under a Memorandum Of Understanding (MOU) with operators who had a proven record at the time in the fishery. There were five signatories to this MOU.

The market collapsed in 1991 and resulted in significant volumes of un-sold catch (sold up to 12 months later at substantial losses exacerbated by storage cost) and led to a consequent reduction in fishing effort. Price and demand rather than availability of the species drive the supply to the market place for this fishery.

The licensing structure was further refined with the introduction of the *Fisheries Act 1994* that defined a specific finfish endorsement (T4) for the stout whiting trawl fishery and a management area for operation. The new structure formally allowed operators to take both stout and red spot whiting. Four operators currently hold the five boat licence endorsements currently issued. Stout whiting landings by these five boats from the managed area have ranged between 2227 tonnes in 1996 and 498 tonnes in 2000

The successful development of this fishery has been achieved by significant research by operators into market requirements and modification of catching and handling techniques to provide a product in the form that those markets require. The fishery catches other species, as incidental catch, in similar levels to that of other otter-trawl fisheries.

Stout whiting operators have provided catch and effort data and sales documentation to the Department of Primary Industries (DPI) since 1997 to improve the data on which fishery management is based. Stock assessment, on which the Total Allowable Catch (TAC) is based, is undertaken annually. Currently scientific and stock assessment support for the fishery is partially funded through a management levy on the five licences along with DPI financial support. Fishery specific research has been commissioned and funded directly by the operators in the past.

2.3 Biology

Stout whiting are endemic to Australia, occurring between Shark Bay and Fremantle in Western Australia and between Bustard Head and northern New South Wales along the east coast. The stout whiting population along Australia’s East Coast appears to constitute a single stock unit (Ovenden et al, 1999). Its distribution overlaps with the northern distribution of the red spot whiting, also know as the eastern school whiting (*Sillago flindersi*).

Sexually mature fish occur in all areas of the fishery for more than eight months of the year, with peak spawning in the summer months (December to February). Stout whiting grow to a maximum size at 23cm fork length (FL) at five years of age. Adult stout whiting often form relatively dense schools on sandy substrates and trawling activities are confined to these areas. It is suspected that schooling aggregations most often form at dawn and dusk. Juvenile fish less than one year of age (< 10cm FL) occur in shallow waters adjacent to ocean surf beaches. Stout whiting are fast growing and move offshore into depths greater than 30 metres at about 1 year old (10 to 13 cm FL).

2.4 Marketing

The stout whiting fishery has an annual gross value of around $3m depending on market prices (AUS$3.10 per kg in 2002) and volume caught. Stout whiting is sold principally for on-processing either in Thailand, China, Vietnam, Japan or Taiwan for the Japanese Kisu-Hiraki style (butterfly) fillet market for use as finger-food. Some product is re-exported to local Australian markets. Overseas fisheries have the capacity to cause gluts in these markets and substantial fluctuations in price can result.

DPI has stated that the fish is "one of the most harvestable fish species in south-east Queensland waters". They also identified a need to promote greater economic stability in the fishery to recognise the influence of external fisheries on market supplies. The reasoning is that the successful development of alternative export markets and strategies is necessary to stabilise demand and enable participants in the fishery to plan future commercial development.

Substantial investigations have been made of alternate markets and of value adding the product locally.

2.5 Management

Five boats (four operators) are licensed to operate in the stout whiting trawl fishery during the fishing season which runs from 1 April to 31 December each year. A voluntary industry-agreed Total Allowable Catch (TAC) is used to manage the fishery. The TAC is negotiated annually and divided equally among the five licensed vessels. Fishing is restricted within the management area located between Caloundra and Sandy Cape in waters between 20 and 50 fathoms as shown in Figure 2.1. Restrictions on fishing gear include:

- The net head rope length must not exceed 44 metres and must have a mesh size of at least 38 mm but not more than 60 mm.
- A net's sweeps must not be longer than 128 metres (420 ft) each.
- A net must not be used from a vessel longer than 20 metres.

The fishery functions under the regulations and a voluntary agreement between the Queensland Fisheries Service and operators as to the appropriate TAC level.

Two major prawn trawl closures were introduced in 2000. Stout whiting vessels elected not to fish during the first southern closure from midday on 20th September to midday on 1st November in 2000, 2001 and 2002.

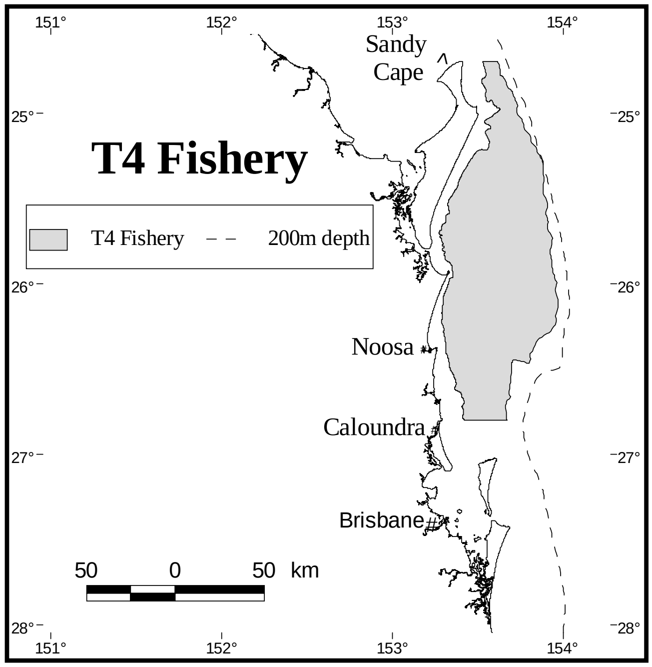


Figure 2.1 Managed area for the stout whiting fishery.

2.6 Previous Assessments

In 1994 the stout whiting stock in Queensland was first assessed using a length-based Cohort Analysis (known as: LCA). This model estimated annual biomass and calculated an $F_{0.1}$ harvest strategy. After the 1995 fishing year, the Queensland Fisheries Management Authority expressed concern over the level of exploitation in the stout whiting fishery. They also expressed reservations about the method of stock assessment. The length-based analysis was originally chosen over an age-based assessment because more categories could be used with length-classes than with age-classes in the fishery. This was thought to provide a more statistically robust method of assessment. However, the length-based method assumed incorrectly that the resource was in equilibrium, whereas an aged based assessment does not.

Globally, the $F_{0.1}$ estimate of fishing mortality is considered an effective management policy for finfish-trawl fisheries, assuming accurate estimates of population size and implementation. Since 1997, the Department of Primary Industries have assessed the stout whiting stock using four different methods. These were:

i) Length Cohort Analysis (LCA) (in this case the model assumes an equilibrium population),
ii) Yield-per-recruit analysis (YPR) (also assumes equilibrium),
iii) Age based Virtual Population Analysis model (VPA) (a dynamic model), and
iv) Surplus Production model (SPM) (also a dynamic model).

The licence holders each contribute approximately $5,000 annually to cover the cost of monitoring, administration and management of the fishery. Additionally, in 1999 the licence holders funded a genetics research study to determine aspects of the stout whiting stock structure (Appendix 6.3).

3. 2003 ASSESSMENT

3.1 Advances from the 2002 assessment

Since 1991, catch and effort statistics have been used to monitor and assess the stout whiting fishery. However, the ongoing development and adoption of technological changes within the fishery have not been included as part of the monitoring process. The performance of the fishing industry may have changed over the years because of the adoption of Global Positioning Systems (GPS) and plotters, the use of sonar, changes to vessel motors and propellers, communication systems and perhaps skipper experience. This has created uncertainty over how well estimates of catch rates reflect the status of stout whiting stock.

In January 2003 questionnaires were again completed with owners and skippers to provide information to establish the catching ability of each vessel in the fishery. This information was used in the 2003 assessment of the stout whiting resource. A statistical analysis was used to examine what effects of vessel characteristics (eg net size, sweep length etc) influence a vessel’s fishing power. The result was then used to estimate average catch rates to provide a better index relative to stock abundance. The analysis essentially makes catch rates between boats and between years more comparable by removing the effects of vessel differences from the CPUE signal.

This year’s assessment was based on three models: a monthly age-structured, virtual population analysis and surplus production models. The first of these three models is still in development and aims to capture more accurately the dynamic nature of the fishery, in that recruitment and biomass are estimated every month. The LCA and YPR models were not considered worthwhile persisting with because of their restricting equilibrium assumptions of constant total biomass and recruitment from year to year. These two models were also reliant on the deterministic von Bertalanffy (age versus fish length) growth equation for relating fish weight, length and age parameters.

3.2 Methods

3.2.1 Data

The data on which the 2003 assessment was based included:

1. Commercial catches from each vessel on a trawl shot basis collated by Southern Fisheries Centre from 1991 to 1999. Catches from 2000 to 2002 were extracted from the Queensland Fisheries Service QFISH data system by a non-aggregated retrieval. Trawl shots where no stout whiting were caught, although were targeted, had to be extracted separately to the non-zero catches.

2. Random fish samples from the stout whiting (T4) catch, collected for length-frequency and aging. The sampling details were-
   - Two 5kg boxes collected from each vessel's fishing trip.
   - All fish from each box were measured for length frequency
   - In total, the first thirty fish from every size class were dissected to extract otoliths, sex and measure gonad weight.
   - The number of samples collected is shown in Table 3.1
3. Fish age determination - both otoliths (sagittae) were removed, cleaned and stored in a labelled plastic bag. Whole otoliths for aging were submerged in vegetable oil and viewed with reflected light under a compound microscope. All otolith reading was done without knowledge of fish size, date or location of capture. Age estimates recorded were counts of complete opaque rings.

Table 3.1 Number of samples collected for the 2003 stout whiting assessment.

Sample	2001	2002
Number of boxes collected	58 17kg-boxes	61 5kg-boxes
Number of fish measured	21416 from the 58 boxes	8391 from the 61 boxes
Number of fish where otoliths were extracted and gonad weight was recorded	964	554
Number of fish aged for assessment	338	554

3.2.2 Statistical analysis of fish catches

The managed area T4 catch and effort records for the fishing season from 1st April to 31st December were analysed from 1991 to 2002. The analysis used a generalised linear model (McCullagh and Nelder, 1989) to identify which variables influence catches of stout whiting and to estimate standardised average catch rates for each year and month. The data analysed were daily catches of stout whiting (kgs) and effort (hours fished and trawls completed) per vessel for each region. Spatial variations in catches were allowed for by dividing the managed area into five regions each corresponding to 30-minute latitude areas. Region 1 included the logbook grids w32 and x32, region 2 included grids w33 and x33, region 3 included grids w34 and x34, region 4 included grids w35 and x35, and region 5 included grids w36 and x36 (Figure 3.2). The analysis included variables to account for variation in daily catches between years, months, lunar phases, fishing regions, fishing depths, boats, skippers, net size, net mesh size, bridle and sweep lengths, and otter board types.

The statistical software Genstat 5 (2000) was used to carry out the estimation by least squares, and provide standard errors for all estimates. A logarithmic transformation was used to linearise the GLM and to normalise the residuals. The Genstat procedure "Select" was used to define the final model structure using Akaike's information criteria for inclusion and exclusion of model terms. Definition of the final generalised linear model (GLM) and its component were as follows:

Catch Rate response variate: log(catch per boat per day per region)
Fitted terms: constant + log(hours fished) + log(number of trawls) + year * month + lunar + region + log(fishing depth) + boat + skipper + log(net size)+log(mesh size)+log(bridle length)+log(sweep length)+otter_board_type

- Catch Rate – sum stout whiting catch (kgs) per boat per day per fishing region
- Hours fished – sum hours fished per boat per day per fishing region
- Trawls – number of trawls per boat per day per region
- Year - 1991 to 2002
- Month – April to December
- Lunar phase – new moon, making moon, full moon and waning moon
- Region – 5 regions as described above
- Fishing depth – measured in fathoms
- Boat – 8 boats (Amanda Jane, Impact (2 owners), Mundurra, San Antone II, Seeker and Valkyrie Voyager (2 owners))
- Skippers type – individual skipper codes
- Net Size (fathoms)
- Mesh size (inches)
- Bridle length (ft)
- Sweep Length (ft)
- Otter board type – bison, flat or v-boards

The average daily catch rate of stout whiting was estimated by using the terms in the model. The resulting average catch rate was for an average standardised boat and skipper through time.

3.2.3 Stock Assessment Models

3.2.3.1 Integrated Age Structured Model

An integrated age model was used to calculate monthly population biomass and numbers of stout whiting. It used an age structured approach that kept track of 1,2,…,72 month old whiting. This class of model is similar to the integrated analysis used to assess the school whiting stock in Australia's south-east trawl fishery (Punt 1999). The population dynamics were assumed to follow the standard Baranov equations. Initial population numbers for fish aged one month in January 1991 was:

$$N_{1991,1,1} = \hat{R}_{1991}\Phi_1$$

where $N_{1991,1,1}$ was the total population in year 1991 for the month January of age one month, $\hat{R}_{1991}$ was the estimated recruitment for year 1991, and Φ_1 was the birth pattern for January (described later as the 'recruitment pattern').

Numbers of fish in 1991 for ages 2 to 72 months were calculated as follows:

$$N_{1991,1,a} = \hat{R}_{av} \Phi_m e^{-1.5M(a-1)}$$

where $N_{1991,1,a}$ were the total population numbers in year 1991 for January aged a, $\hat{R}_{av}$ was the estimated average recruitment for the years 1985 to 1990, Φ_m was the recruitment pattern in month m, and M was the assumed constant average monthly rate of natural mortality across ages.

The age-structured time dynamic calculations after January 1991 followed the equations:

$$N_{y,m,a} = \begin{cases} R_y \Phi_m \text{ for a} = 1 \\ N_{y,m-1,a-1} e^{-M-\left(1-S_{a-1}F_{y,m-1}\right)} \text{ for a} = 1..12 \end{cases},$$

where R_y were the estimated annual recruitments for the years 1992 to 2002.

The recruitment pattern Φ_m represents the proportion of annual recruits in each month m, and was calculated by the following equation:

$$\Phi_m = e^{\left(\frac{-\left((m-\mu_r)^2\right)^{\theta_r}}{2\sigma_r^2}\right)},$$

where μ_r, θ_r, and σ_r were recruitment parameters to be estimated. The resulting pattern was normalised to 1.

Monthly fishing mortality, $F_{y,m}$ was calculated as:

$$F_{y,m} = q \frac{C_{y,m}}{qB_{y,m}},$$

where q was the catchability coefficient and $C_{y,m}$ were the observed catches in tonnes for year, y, and month, m.

The fishing selectivity S_a was calculated directly for each age using the logistic equation:

$$S_a = \frac{1}{1+e^{-\log(19)\frac{a-a_{50}}{a_{95}-a_{50}}}},$$

where a_{95} was the estimated age at which selectivity is 95%, and a_{50} was assumed $a_{95}/1.5$.

The exploitable biomass at the start of each month was:

$$B_{y,m} = \sum_a N_{y,m,a} S_a w_a,$$

where w_a was the average fish weight at age (units in tonnes).

The model estimate of monthly catch (in tonnes) was given by:

$$C_{y,m} = \frac{F_{y,m}}{F_{y,m}+M} B_{y,m} \left(1 - e^{-F_{y,m}-M}\right)$$

In total 18 parameters were estimated in the age-structured model. These parameters and the ones assumed are outlined in Table 3.2. The model was fit to the observed catch age-structure and monthly fishing-power standardised catch rates from January 1991 to December 2002. The 'fminsearch' MATLAB (2002) simplex search routine was used to carry out the estimation by maximum likelihood. The negative log-likelihood function considered here had two components. The first was based on the observation that the total catch (in number) and the age-composition of the catch are estimated independently, and so should be included as separate components in the first likelihood function:

$$-\log L_1 = \sum_y \log(\sigma_1) + \frac{1}{2\sigma_1^{\,2}}\left(\log \sum_a C_{y,m,a} - \log \sum_a \hat{C}_{y,m,a}\right)^2 +$$

$$\sum_y \sum_a \log\left(\sigma_2 / \sqrt{\hat{p}_{y,a}}\right) + \frac{\hat{p}_{y,a}}{2\sigma_2^{\,2}}\left(\log(p_{y,a}) - \log(\hat{p}_{y,a})\right)^2$$

where $p_{y,a}$ was the observed fraction of fish aged a that made up the catch during year y:

$$p_{y,a} = \frac{C_{y,a}}{\sum_a C_{y,a}}$$

and $\hat{p}_{y,a}$ was the model predicted fraction of fish aged a that made up the catch during year y.

The second likelihood function was for the catch rate data:

$$-\log L_2 = \frac{n}{2}\left(\log(2\pi) + 2\log\left(sqrt\left(\frac{1}{n}\sum_t \left(\log\left(cpue_t\right) - \log\left(\overset{\wedge}{cpue_t}\right)\right)^2\right)\right) + 1\right),$$

where n was number of observed catch rates, π is 3.14159265358979, log is the natural logarithm function, *sqrt* is the square root function and *cpue* was the monthly standardised catch rate and $\overset{\wedge}{cpue}$ was the predicted catch rate. The predict monthly catch rate was according to the relationship $\overset{\wedge}{cpue} = qB_{y,m}$.

The total negative log likelihood for the model was $-\log L_1 + -\log L_2$.

Overall, the main assumptions of the age-structure analyses were:

- Standardised catch rate was proportional to abundance.
- Constant monthly natural mortality.
- Constant average fish growth
- Constant average recruitment pattern.
- Accurate reporting of the commercial catches and accurate fish aging.

In most stock assessments where input parameters within the model are deterministic, the effects on the results of entering different parameter values are tested. This is known as model sensitivity analysis. This means that it is necessary to select parameter values that best represent our knowledge of the resource and treat these as the base case against which any changes are being compared. The sensitivity of the model was tested with annual natural mortality values of 0.6, 0.7 and 0.8. Only one parameter value was changed at a time. Overall, two different scenarios were examined.

Table 3.2 List of parameters used in the model.

Estimated Parameters	Fixed parameters (Assumed known)
Catchability *q*	Monthly Natural Mortality M = 0.0583 or 0.05 (Dichmont and Butcher, 1998)
Recruitment shape parameters μ_r ,θ_r , σ_r	Length/weight relationship (Butcher and Brown 1995) wt_age=[0.012533481*l_age.^2.91290293]./1000000;
Age at 95% selectivity a_{95}	Growth Curve (Butcher and Brown, 1995) l_age=22.29*(1-exp(-(0.459/12).*(age+1.03)));
Annual recruitments R_y 1991 to 2002	
Average recruitment R_{av} 1985 to 1990	

3.2.3.2 Management strategy evaluation

On completion of the base stock assessment, the performance of TAC reference points were tested through a series of simulations. The algorithm used for the simulations was similar to the forward projection methods used by Richards *et al*. (1998). The average results from the simulations were summarised in a management strategy evaluation (MSE) (Smith 1994). Management strategy evaluation involves assessing the consequences of a range of fishing strategies and presents the results in a way that lays bare the trade-offs in performance across a range of management objectives. The approach does not define a final fishing strategy or decision. It only provides information on which to base management choices, given a set of management objectives. To fully understand the structure of the MSE, the following key elements and definitions were used:

- The ***fishing strategies*** were the fishing mortality rates allowed in the fishery each year. The fishing strategies examined included maximum sustainable yield (MSY), ¾ MSY, 2/3 MSY, $F_{0.1}$, 0.5M, status quo (2002 fishing effort) and 1000 t constant catch per year.
- The ***management strategy*** was the decision to change the TAC annually according to the fishing strategies and the population estimates in the fishery.
- The ***management objectives*** considered biological sustainability and industry sustainability.
- A number of different ***performance measures*** were used to gauge each ***fishing strategy*** against the ***management objectives***.
  Two quantitative measures of biological sustainability were used:
  1. The risk over a 10-year period of management that the stock size will fall below 20% of the equilibrium virgin (unfished) population biomass. The 20% value is not meant to represent the threshold of recruitment overfishing, but rather to indicate that the stock has been substantially fished down.
  2. The risk over a 10-year period of management that the stock size will fall below the long-term equilibrium population biomass that results from fishing the stock at maximum sustainable yield (B_{MSY}).

  Three quantitative measures of industry sustainability were used:
  1. The median total catch expected at the end of the 10-year period of management.
  2. The median variation in total catch over the 10-year period of management (average coefficient of variation).

3. The median daily catch per boat over the 10-year period of management.

3.2.3.3 Virtual Population Analysis (VPA)

Virtual Population Analysis, also known as cohort analysis, is a time dynamic model, which calculates past stock abundances based on past catches. This was done by calculating the number of fish alive in each cohort (age class) for each past year. Each cohort was analysed separately. Thus the VPA relies on a very simple relationship for each cohort. This is that the number alive at the beginning of next year is equal to the number alive at the beginning of this year and removing deaths incurred during the year due to fishing and natural mortality. In this analysis of the stout whiting resource, a Laurec-Shepherd *ad hoc* tuned VPA is used as described in Punt (1992, 1997).

In the VPA the input parameters are the age at which recruitment into the fishery occurs, the age at 50% maturity, natural mortality for each age and the shape of the selectivity curve. The base case for stout whiting was chosen as:

- age at recruitment was zero+ (ie. all ages are fully available to be caught),
- age at 50% maturity is two+,
- natural mortality is 0.6 yr^{-1},
- the selectivity ogive (γ) in Equation 1 of Punt (1992) is zero, and
- the initial and final beta (β) values were those giving a flat selectivity function once full selection occurs.

3.2.3.4 Surplus production model (SPM)

The simplest time dynamic fisheries population models are those that consider only a single indicator of population size, usually biomass. These models ignore age or size structure and do not explicitly consider growth and recruitment. They are called biomass dynamic (or surplus production) models and take several variations on the traditional logistic models of ecology. The most commonly used of these is the Schaefer form of the surplus production model. Only two main parameters are to be estimated which makes it usually very robust. These are the intrinsic population growth rate (r) and the population carrying capacity (K). The model used for this analysis is described in Punt (1993). It relies on the catch per unit effort index being proportional to the trend in stock abundance.

3.3 Results

3.3.1 Catch and effort

The Queensland stout whiting trawl fishery (T4) is limited to five vessels. Annual T4 landings taken from the managed area increased from 529 tonnes in 1991 to 2227 t in 1996. Since 1996 annual landings have declined to 498 t in 2000. The 2001 and 2002 catches increased to 881 t and 855 t respectively (Figure 3.1 and Table 3.3). The annual level of fishing effort (measured in hours) had the same pattern. A history of all stout whiting catches and effort by T4 endorsed vessels with different gears and areas are given in appendix 6.1 (Table 6.1). In the last four years the bulk of catches were taken from the Fraser island region (Figure 3.2 and Figure 3.3).

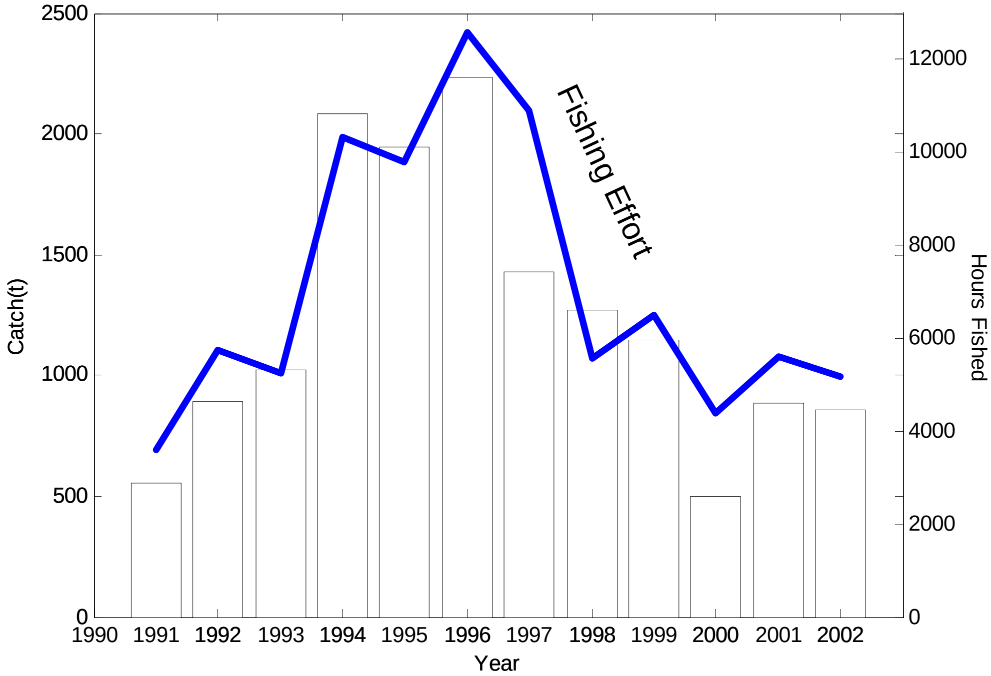
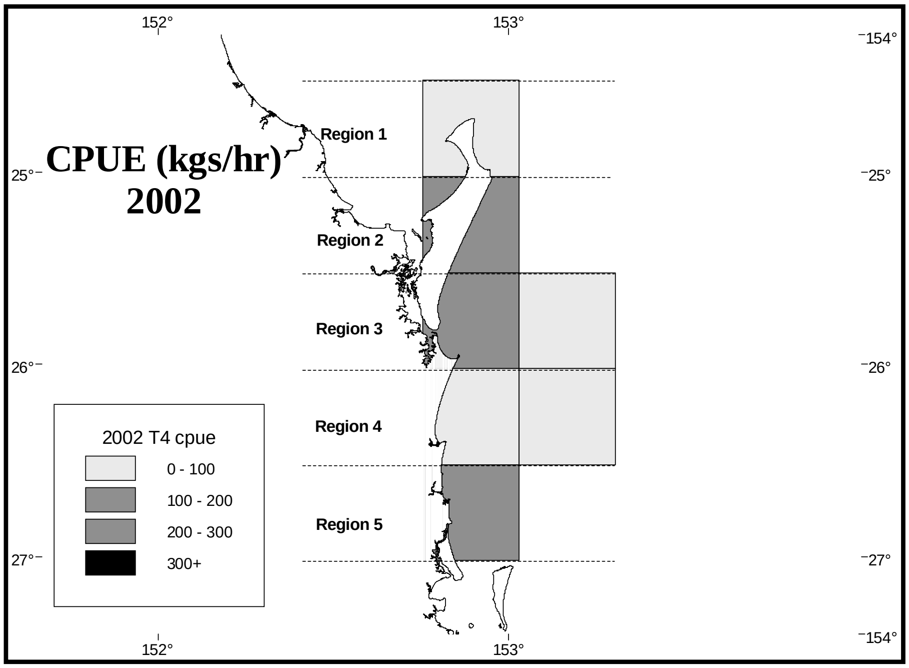


Figure 3.1 Queensland T4 stout whiting catch (t) and nominal effort (hours) for the managed area.

Table 3.3 Tabulated Queensland T4 stout whiting catch (t) and nominal effort (hours) for the managed area.

Year	Catch (t)	Effort (hours)	Number of Boats
1991	529	3613	5
1992	894	5736	4
1993	1001	5242	3
1994	1959	10330	4
1995	1965	9806	4
1996	2227	12577	5
1997	1403	10903	5
1998	1074	5560	5
1999	914	6492	5
2000	498	4391	4
2001	881	5622	5
2002	855	5174	5



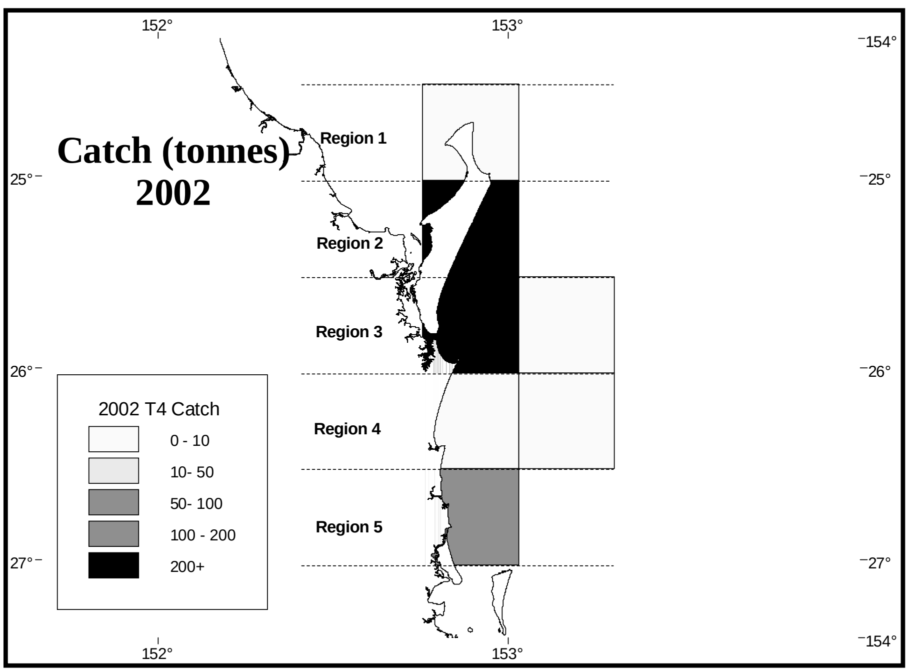


Figure 3.2 Spatial distribution of T4 stout whiting catch rates and catches in 2002.

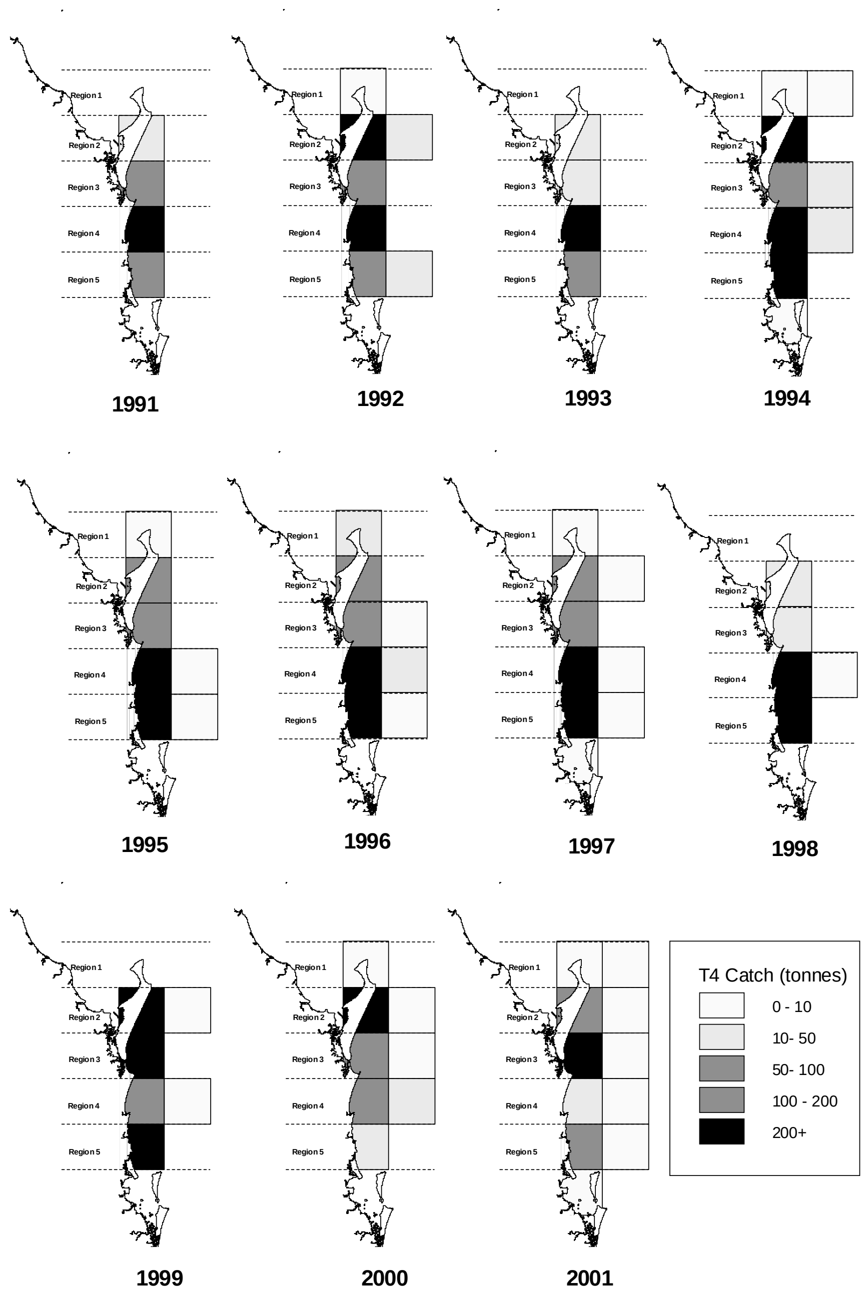


Figure 3.3 Spatial distribution of T4 stout whiting catches in the managed area by logbook 30 minute grid sites from 1991 to 2001.

3.3.2 Analysis of stout whiting catches

A generalised linear regression model (GLM) was applied to the daily catches of stout whiting (Table 3.4). The table lists the significant variables influencing stout whiting catches. These effects were standardised to estimate an average monthly abundance index (catch rates) within the managed area, assuming the catch rate index of stout whiting is representative of population abundance (Figure 3.4). In general, the monthly catch rates were higher between 1992 and 1998, compared to the last three years of 2000 to 2002. The highest catch rate occurred in April 1996. Catch rates were lowest in 2000, but increased with stable catch rates between 2001 and 2002. The fishery observed annual catch rate measured in kilograms per hour shows the same trend (Figure 3.5).

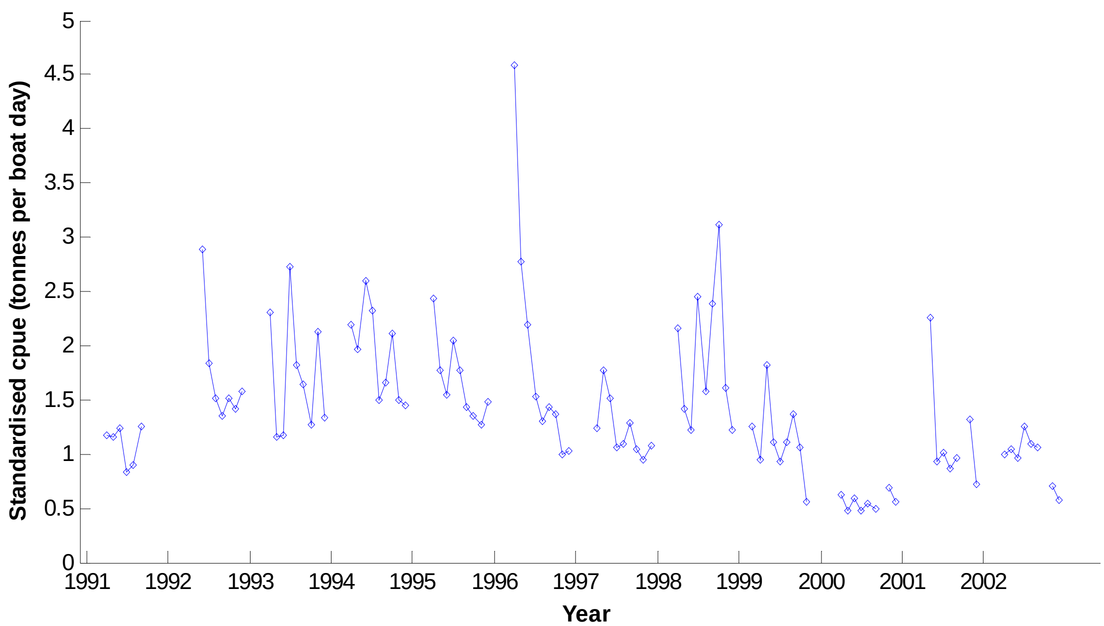


Figure 3.4 Monthly standardised catch-per-unit effort (cpue). The cpue index represents a standardised average vessel and skipper through time; fishing in a standardised region, lunar phase and depth; actively trawling for eight hours a day.

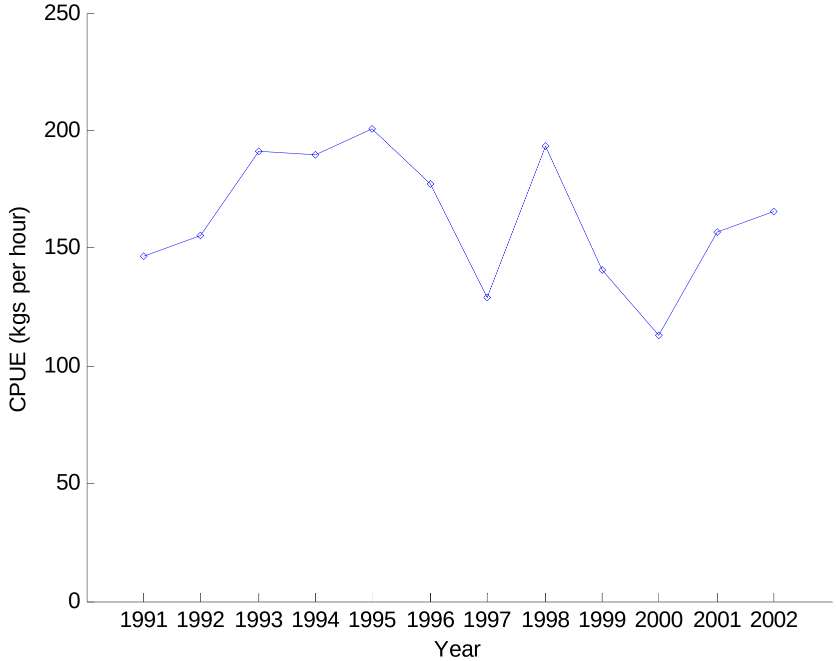


Figure 3.5 Observed average catch-per-unit-effort (CPUE kg per hour per boat).

Table 3.4 Type I ANOVA results for the generalised linear model of stout whiting catches. Percent variance accounted for was 58.4%.

Source	**df**	**SS**	**MS**	**Variance Ratio**	**F *Probability***
lnhours	1	5389.776	5389.776	8688.34	<.001
lntrawls	1	128.2856	128.2856	206.8	<.001
year	11	578.8212	52.6201	84.82	<.001
month	8	231.8819	28.9852	46.72	<.001
year.month	77	344.1026	4.4689	7.2	<.001
lunar	3	24.0372	8.0124	12.92	<.001
region	4	47.4048	11.8512	19.1	<.001
lndepth	1	4.4812	4.4812	7.22	0.007
boat	7	59.5501	8.5072	13.71	<.001
skipper	19	29.6751	1.5618	2.52	<.001
lnnetsz	1	15.3034	15.3034	24.67	<.001
lnmesh	1	24.1022	24.1022	38.85	<.001
lnbridle	1	23.3547	23.3547	37.65	<.001
lnsweep	1	16.9886	16.9886	27.39	<.001
board	1	3.6033	3.6033	5.81	0.016
Regression	137	6921	50.5209	81.44	<.001
Residual	7710	4783	0.6203		
Total	7847	11704	1.4916		

Table 3.5 Tabulated CPUE averages for Figure 3.5.

Year	Observed CPUE (kg/hour)
1991	146.2
1992	155.7
1993	190.8
1994	189.6
1995	200.4
1996	177.0
1997	128.7
1998	193.1
1999	140.7
2000	113.2
2001	156.6
2002	165.2

Figure 3.6 illustrates the average effect of month, region, lunar phase, fishing depth, mesh size and sweep length on stout whiting catches. In general, average catch rates were higher earlier in the fishing season, higher on the days leading up to the full moon, higher with shallower fishing depths within the managed area and higher for boats using larger mesh and longer sweeps. Other effects such as vessel hull units, engine horsepower, trawl speed, gear box reduction and gps/dgps were investigated in the analysis. However, since 1991 the characteristics of these items for each vessel had not changed sufficiently to be incorporated in the final analysis. Therefore, the effects of these variables were grouped into a single boat variable.

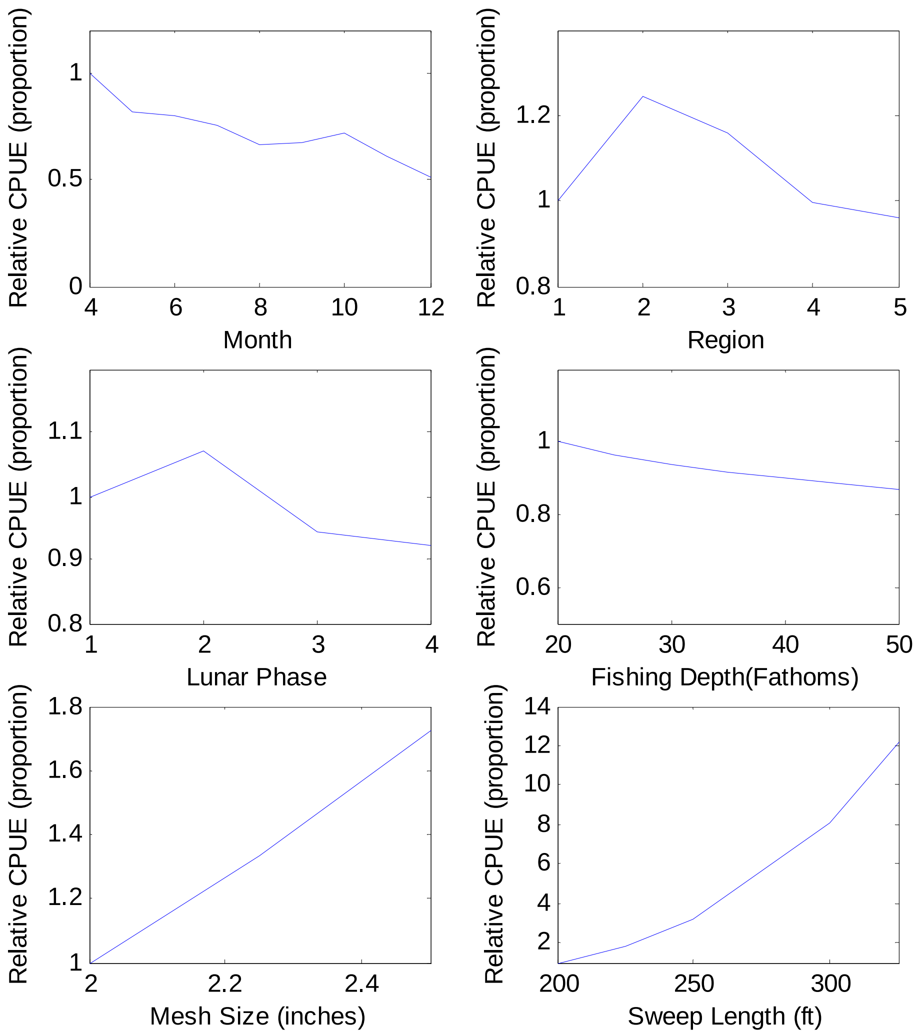


Figure 3.6 Relative average CPUE for the GLM modelled effects of month, fishing region, lunar phase, fishing depth (fathoms), mesh size (inches) and sweep length (ft). Note that all values represent the proportion change in catch rate relative to the standard value of 1 (month = 4 (April) , region = 1 (w32), lunar phase = 1, depth = 20 fm, mesh size = 2 inches, and sweep length = 200 ft). The coding for lunar phases were 1 = new moon, 2 = making moon, 3 = full moon and 4= waning moon; for fishing regions 1 = w32, 2 = w33, 3 = w34, 4 = w35 and 5 = w36).

3.3.3 Size structure

The size structures of stout whiting caught between 1991 and 1999 were relatively similar (Figure 3.7). However, the sizes of stout whiting caught from 2000 to 2002 were slightly smaller. The average fish size caught between 1991 and 1999 was 16.7 cm, compared to 15.7 cm between 2000 and 2002. Two modal size structures appeared in the 2000 and 2001 catch around 13-14 cm and 17cm. The same pattern also occurred in 1994, although the bi-modal signal was weak. The size at which 50% of female fish have attained their sexual maturity is 14.5 cm.

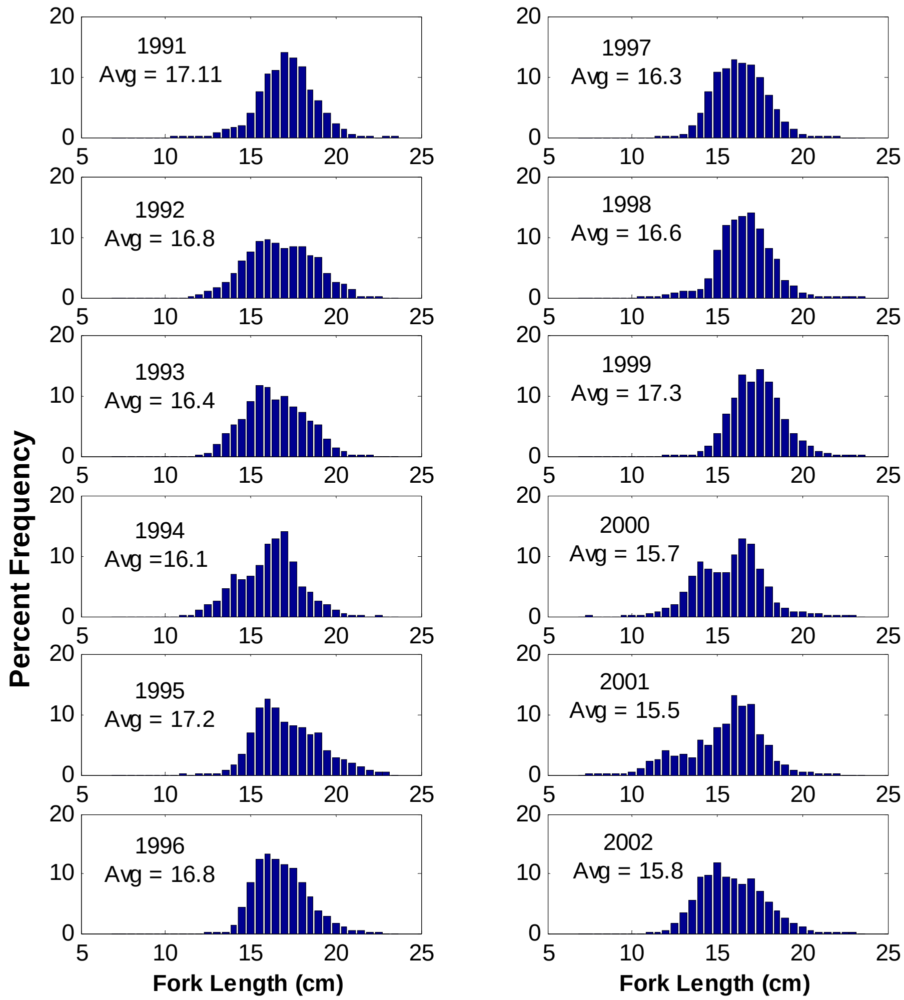
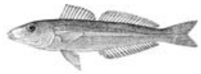


Figure 3.7 Size structure (percent frequency) of stout whiting caught from 1991 to 2002 (MA).



3.3.4 Age structure

Stout whiting catches from 1991 to 2000 were based heavily on the abundance of young fish aged 0+ and 1+ years old (about 75% of the age structure) (Figure 3.8). However, in 2001 and 2002 fish aged 2 years and older dominated the age structure (58% and 67% for the two years respectively). The oldest fish observed in the catches was 5+ years old and comprised less than two percent of the annual catches. In 1999 the percent of fish aged 0+ dropped considerably to 7%. This was a concern given the percentage of 0+ fish in each year's catch from 1991 to 1996 ranged between 22 and 42%. In 2000 and 2001 the percentage of 0+ fish increased to 16% and 19% respectively. In 2002 this percentage dropped to 5%.

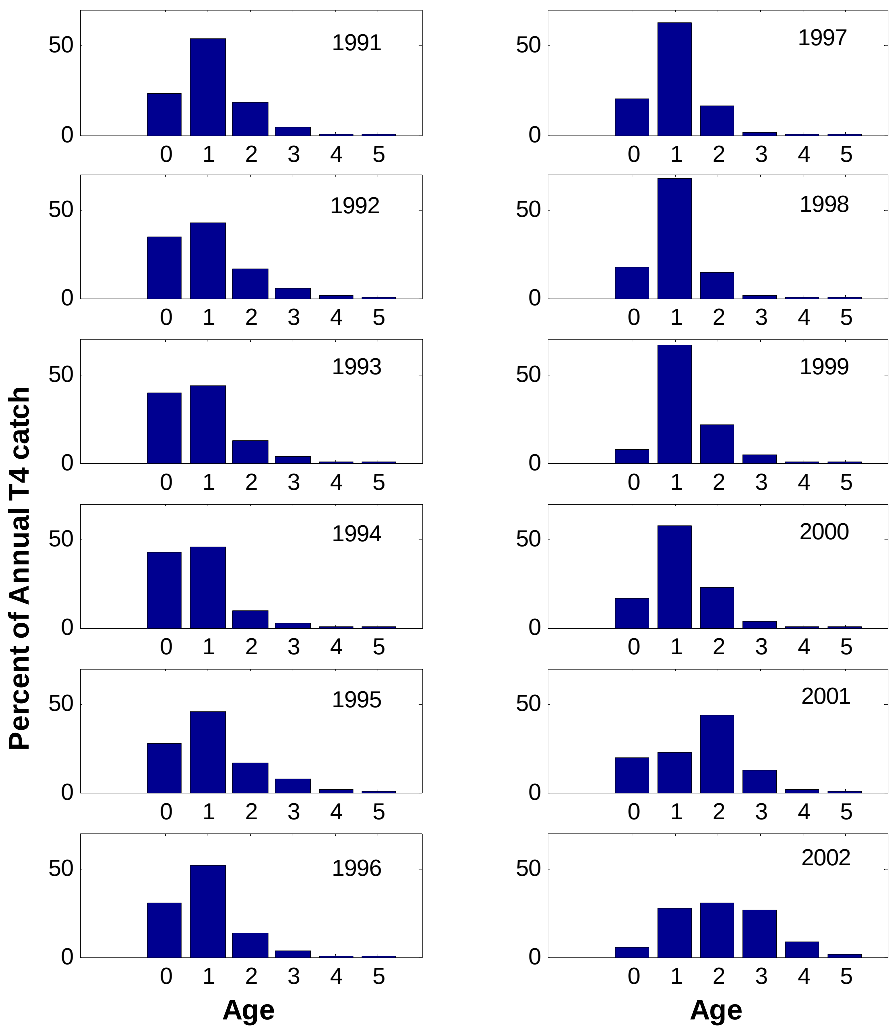


Figure 3.8 Age structure (percent frequency) of stout whiting caught from 1991 to 2002.

In the last two assessments there has been a concern about the readability of stout whiting whole otoliths. Comparison of age readings between different readers showed large discrepancies. This was in contrast to the preferred whole otolith readings recommended by Butcher and Brown (1995). This issue was a major concern for accuracy of the age based stock assessment. In February 2002 additional work was funded to verify the accuracy of aging stout whiting and whether whole or sectioned ageing is the preferred method. A total of 500 stout whiting otoliths from the 2001 fishery were forwarded to the Central Aging Facility (CAF), Marine and Freshwater Resources Institute, Victoria, to age. They found the same maximum and minimum ages, sectioned otoliths displayed slightly better readability than whole otoliths, and greater precision was achieved when re-reading sectioned otoliths than with whole otoliths. However, after comparing whole and sectioned ages, they concluded that ages from whole otoliths would be appropriate for routine stock assessment. Figure 3.9 shows whole and sectioned otolith readings from two fish, illustrating the difficulty in aging stout whiting.

a) Five year old fish **b) Two year old fish**

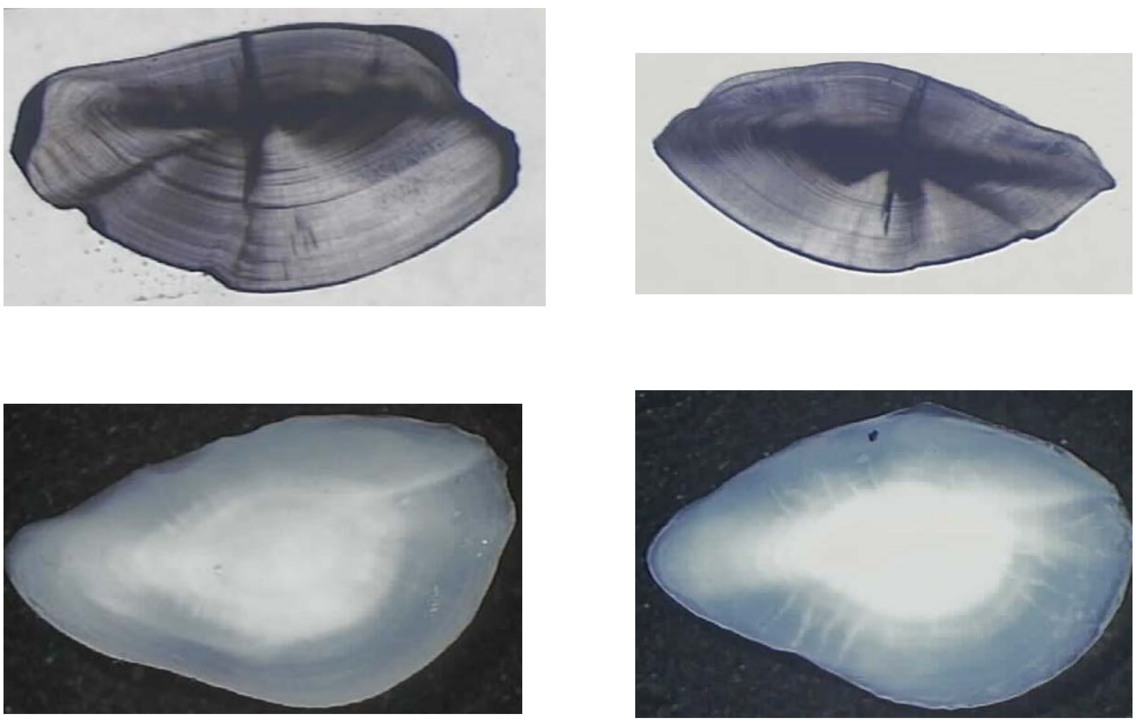


Figure 3.9 Microscope view comparing sectioned (above) and whole (below) otolith readings from a) 19 cm FL fish aged five years on the left (fishno. 526003265) and b) a 15.5 cm FL fish age two years on the right (fishno. 526003297).

3.3.5 Reproductive Patterns (GSI trends)

Average gonosomatic index (GSI) for each month was estimated by fitting a generalised linear model. Gonad weight (square root transformed) was modelled against fish weight, year and month factors for male and female fish separately. GSI was estimated by the model monthly means (adjusted by the squared power). For both male and female stout whiting, there was a significant change in GSI between months. The gonad index peaked (for both sexes) during the months of August, September and October (Figure 3.10).

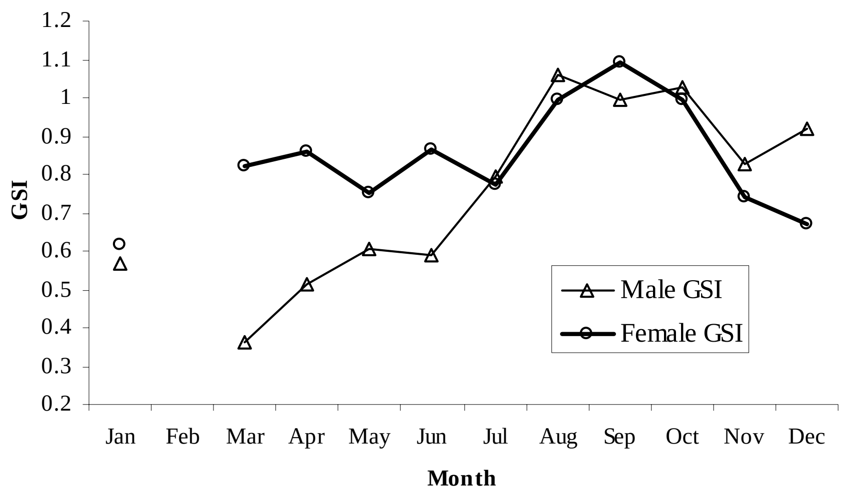


Figure 3.10 Stout whiting average monthly GSI for the years 1999 and 2000 combined (male fish n = 1468 and female fish n = 1344)

3.3.6 Integrated Analysis

Here, the integrated age-structured model was tuned to the standardised monthly catch-rates and annual age-structures. Although this model is still at an early stage of development, it tracked the general trend in the catch rates quite well (Figure 3.11). However, the plot of standardised residuals highlights a few of the large catch-rates were under-estimated and a few of the low catch rates were over estimated (Figure 3.12). In addition, the model predicted the observed age-structure from 1991 to 2000 reasonably well, but failed to explain the drop in proportion 1+ aged fish in 2001 and 2002 (Figure 3.13). Improved fits to the 2001 and 2002 age-structure were obtained by relaxing the catch-rate fitting procedure, but this resulted in a more pessimistic estimate of recruitment for those years.

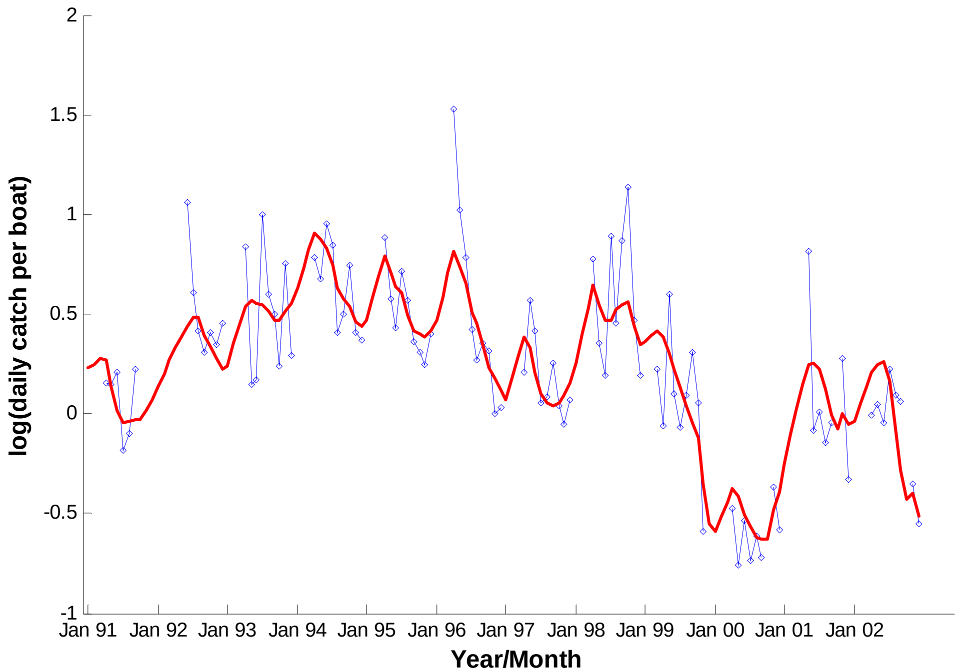


Figure 3.11 Comparison of standardised catch-rates and the integrated model's predicted catch-rates

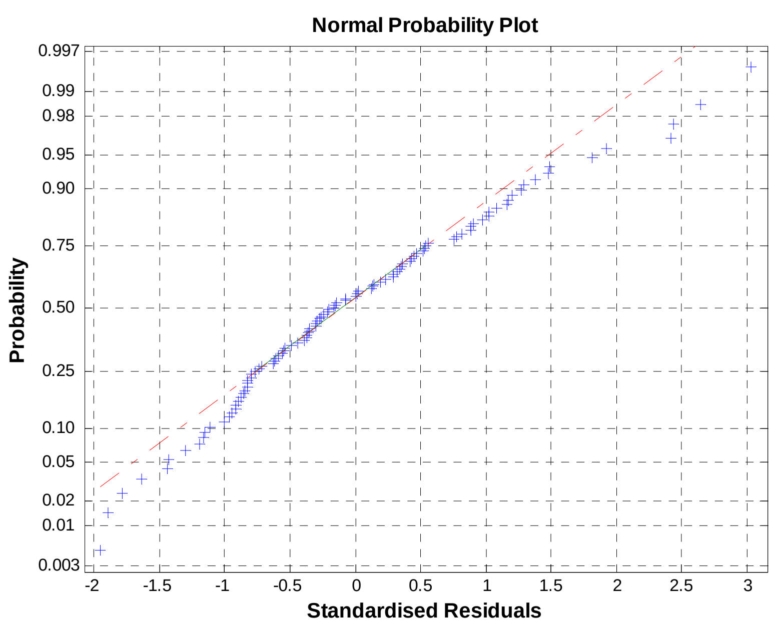


Figure 3.12 Normal probability plot of standardised residuals.

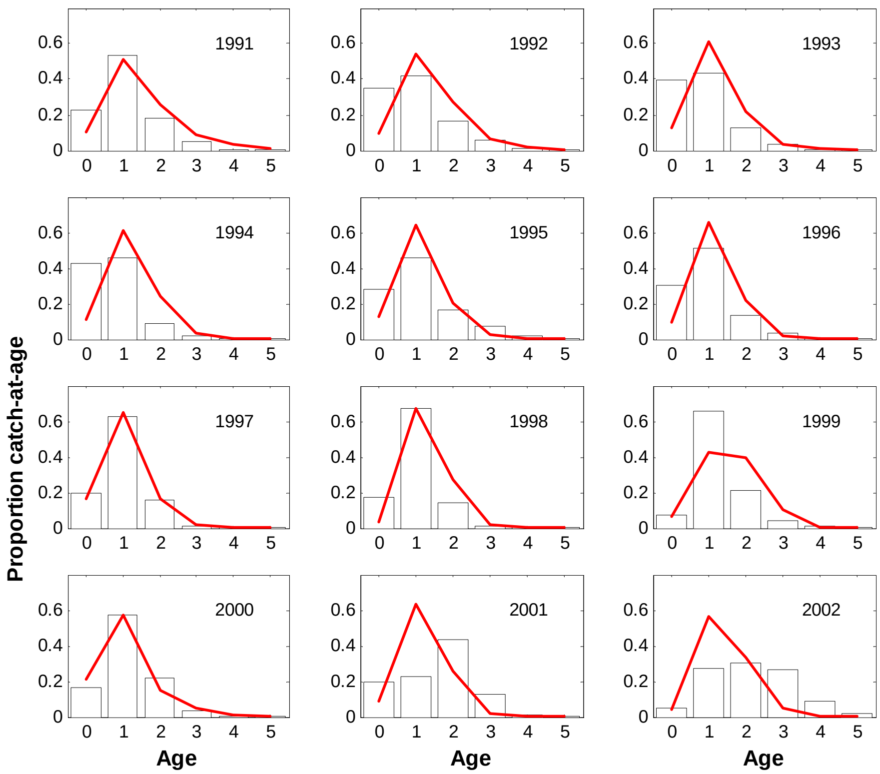


Figure 3.13 Comparison of the integrated model's predicted proportion of catch-at-age against the observed proportion.

The integrated model was applied for two assumed rates of natural mortality – 0.6 and 0.7 per year. Both analyses showed that recruitment mostly occurred between August and December, and fish were generally vulnerable to fishing by 13cm in size (Figure 3.14). Estimated exploitable biomass and recruitment has declined in the last five years (Figure 3.15).

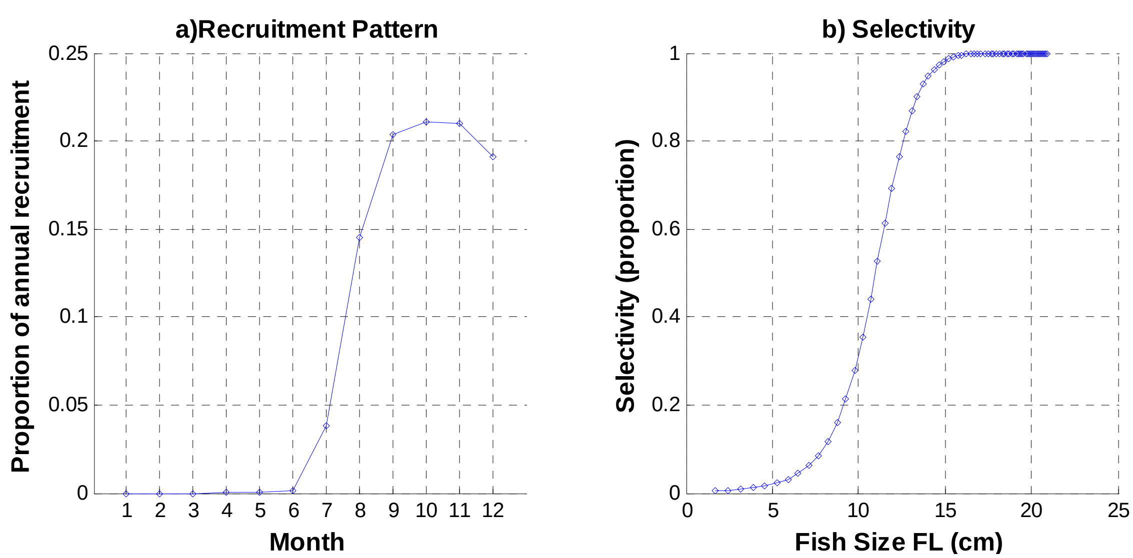


Figure 3.14 Estimated averaged relationships for a) within year recruitment pattern and b) fish selectivity at size.

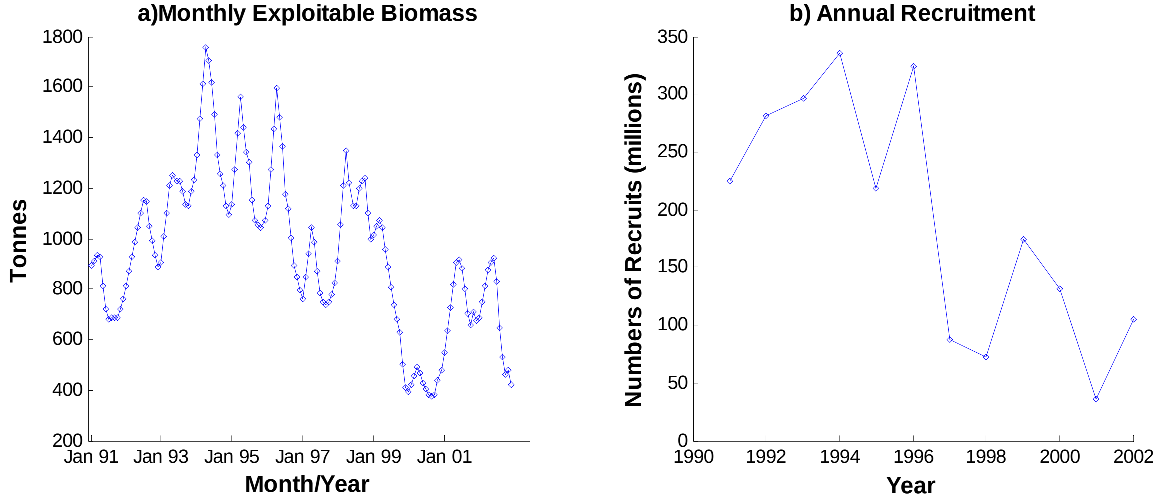


Figure 3.15 Plot of a) estimated exploitable biomass and b) annual recruitment. The biomass reference at maximum sustainable yield is 1019 tonnes (95% CI 519:2110) and at 20% of K is 762 tonnes (95% CI 333:1642).

Table 3.6 contains the relevant TAC calculations and the management strategy evaluation (MSE) to guide selection of the 2003 quota. Management strategy evaluation involves assessing the consequences of a range of fishing strategies and presents the results in a way that lays bare the trade-offs in performance across a range of management objectives. The results do not define a final fishing strategy or decision. It only provides information on which to base quota choices. To fully understand the structure of the MSE table, see the definitions under the methods section 3.2.3.2. The management strategy table suggests that the fishing strategies of ¾ F_{msy}, 2/3 F_{msy}, $F_{0.1}$ and ½ M will result in the lowest risk of the exploitable biomass falling below 20% of K, and that a safe target biomass level above B_{msy} will be achieved (Table 3.6; grey shaded cells). This interpretation was based on using the criteria that the probability of the biomass falling below 20% of K should not be greater than 0.1 (Francis and Shotton 1997). The resulting average catches at these fishing strategies after 10 years is between 700 to 950. The ½ M fishing strategy results in the lowest risk, lowest variation in catches from year to year and the highest catch rates. Fishing at maximum sustainable yield will result in the best average catch of 975 tonnes from the fishery after 10 years.

Overall, the model estimated the ratio of exploitable biomass in 2002 to the exploitable component of the carrying capacity (B_{2002}/K) at 0.19 (Table 3.7). The ratio of 0.2-0.3 is the general benchmark to indicate over-fishing (Mace and Sissenwine 1993). The results were sensitive to the assumed rate of natural mortality.

Table 3.6 Management strategy table.

Fishing Strategy	2003 TAC (t)	Risk Probability (B_{2012}<0.2K)	Risk Probability (B_{2012}<BMSY)	Ratio (B_{2012}/K)	Ratio (B_{2012}/BMSY)	$CATCH_{2012}$ (t)	CV CATCH	$CPUE_{2012}$ (t/boat day)
1000t	**1000**	0.595	0.614	<0.2	<.5	<500t	1.1516	<0.5t
Status quo	**847** (425:1818)	0.307	0.649	0.24	0.87	969	0.58241	0.92
Fmsy	**835** (409:1800)	0.185	0.49	0.28	1.00	**975**	0.5761	1.08
3/4 Fmsy	**793** (375:1738)	**0.046**	**0.197**	**0.36**	**1.29**	945	0.5694	1.41
2/3 Fmsy	**769** (360:1697)	**0.021**	**0.14**	**0.39**	**1.41**	924	0.56848	1.56
$F_{0.1}$	**705** (322:1582)	**0.005**	**0.046**	**0.47**	**1.69**	869	0.56957	1.92
F=1/2M	**576** (288:1132)	**0**	**0.013**	**0.60**	**2.18**	726	**0.48363**	**2.28**

Table 3.7 Summary of sensitivity results using two different natural mortality rates. B_{2002}/K^e is the ratio of the exploitable biomass in 2002 to the exploitable component of the carrying capacity (K^e). The MSY is the estimate of equilibrium maximum sustainable yield. The upper 95% and lower 5%-iles are given in brackets. The MSY values are given in tonnes.

Parameter	M=0.6yr^{-1}	M=0.7yr^{-1}
B_{2002}/K^e	0.16 (0.07:0.32)	0.19 (0.09:0.43)
MSY	957 (518:1742)	974 (556:1791)

3.3.7 *Virtual Population Analysis*

The VPA analysis used the age structure from the catch and the observed levels of un-standardised fishing effort measured in hours. The model was applied for two assumed rates of natural mortality – 0.6 and 0.7 per year. The results from using the 0.6 natural mortality rate indicates that estimated annual levels of fishing mortality (F) from 1991 to 2002 ranged between 0.3 and 2.2 (Table 3.8). In eight out of the past 12 years the annual level of F exceeded natural mortality (M=0.6). Many of the estimates of F for each age class were greater than M. However, in the years 2000 to 2002 the average estimates of F were less than M. Estimates of F greater than natural mortality may be quite high for stout whiting. Generally, if fishing mortality was greater than natural mortality the fish stock could be viewed as heavily fished (Patterson 1992). Estimated recruitment numbers of fish indicated a steady decline from 2000 to 2002, after a peak in recruitment in 1999 (Figure 3.16). It should be noted that the confidence intervals only relate to the years 1997 to 2002, and that the uncertainty is extremely large on the 1999-recruitment estimate. Overall the VPA predicted the age structure extremely well (Figure 3.17).

Table 3.8 Fishing mortality ($F_{y,a \text{ – by year and age class}}$) of stout whiting from the MA, derived from the base case (M = 0.6, age at maturity = 2) *ad-hoc* tuned VPA. Units are yr^{-1} fish respectively. The bold average annual F values indicate years when fishing mortality (F) exceeded natural mortality (M).

	AGES						
$F_{y,a}$	**0**	**1**	**2**	**3**	**4**	**5**	**Average F**
1991	0.061	0.436	0.612	0.860	0.961	0.909	**0.640**
1992	0.121	0.478	0.790	1.865	2.877	2.316	**1.408**
1993	0.114	0.413	0.495	0.715	1.341	0.979	**0.676**
1994	0.348	0.868	0.618	0.653	0.354	0.481	0.554
1995	0.164	0.855	1.090	2.035	2.663	2.328	**1.522**
1996	0.248	1.163	1.943	2.581	3.876	3.163	**2.162**
1997	0.103	1.165	1.824	0.956	1.888	1.344	**1.213**
1998	0.050	0.642	1.120	0.674	0.555	0.611	**0.609**
1999	0.011	0.305	0.502	1.509	2.355	1.885	**1.094**
2000	0.034	0.122	0.172	0.145	1.254	0.426	0.359
2001	0.126	0.176	0.402	0.448	0.235	0.324	0.285
2002	0.069	0.373	0.541	0.674	0.942	0.797	0.566

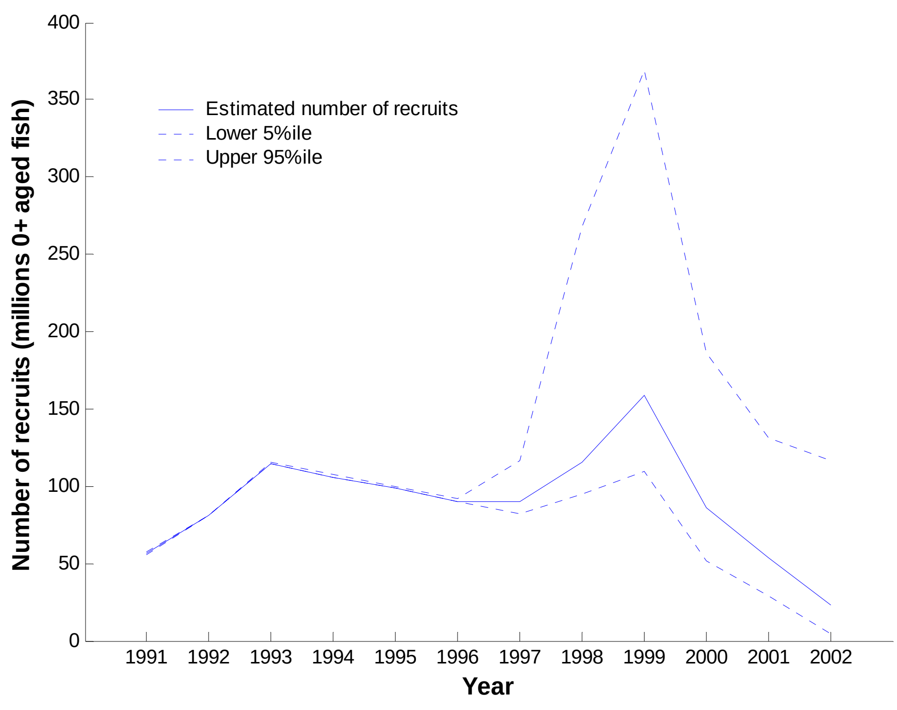


Figure 3.16 Estimated recruitment in the stout whiting managed area fishery between 1991 and 1999, along with their upper 95% and lower 5% percentiles.

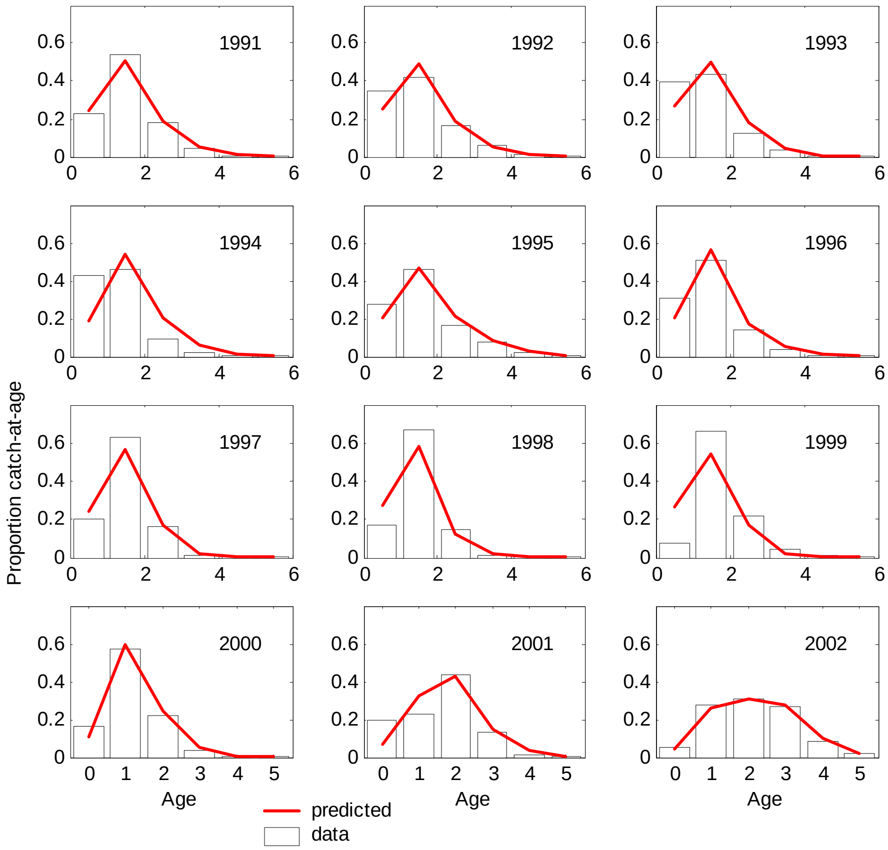


Figure 3.17 Plot of the observed proportion of catch-at-age against the VPA predicted.

Table 3.9 contains the relevant management information. The B_{2002}/K^e is the ratio of the exploitable biomass in 2002 to the exploitable component of the carrying capacity (K^e). This ratio was estimated to be 0.439, indicating the resource is not recruitment over-fished. $TAC_{0.1}$ or TAC_{sq} are the recommended catch strategies for allocating next year's quota. If the $F_{0.1}$ policy is used, the uncertainties from using different natural mortality rates should be considered. The TAC_{sq} is the $F_{status\ quo}$ harvest strategy TAC that aims to keep the level of fishing mortality (effort) at the 2002 level.

Table 3.9 Summary of results of the VPA application using two different natural mortality rates. B_{2002}/K^e is the ratio of the exploitable biomass in 2002 to the exploitable component of the carrying capacity (K^e). $TAC_{0.1}$ is the quota for the 2003 fishing-year if the $F_{0.1}$ policy is being used. The $TAC_{0.2}$ is the quota if the $F_{0.2}$ policy is being used. The TAC_{sq} is the $F_{status\ quo}$ harvest strategy that aims to keep fishing mortality at its current level. The MSY is the estimate of equilibrium maximum sustainable yield. The upper 95% and lower 5%-iles are given in brackets. The MSY and TAC values are given in tonnes.

Parameter	M=0.6yr^{-1} , Age at 50% mat.=2	M=0.7yr^{-1} , Age at 50% mat.=2
B_{2002}/K^e	0.439 (0.17:1)	0.523 (0.22:1)
MSY	1174 (426:3213)	1314 (492:3621)
$TAC_{0.1}$	869 (546:2221)	1403 (894:3691)
$TAC_{0.2}$	518 (321:1338)	750 (477:2077)
TAC_{sq}	627 (390:1619)	618 (389:1726)

3.3.8 Surplus Production Analysis

The surplus production model was applied to the standardised average annual catch rate (Figure 3.18). The model fit was poor, as it could not predict the catch rates accurately. The biomass in 1991 was calculated, rather than assumed to be at virgin stock size. Management parameters derived from the surplus production model are presented in Table 3.10. The B_{2002}/K ratio was estimated to be at 0.18, indicating that resource levels are quite low compared to estimated virgin stock size (carrying capacity).

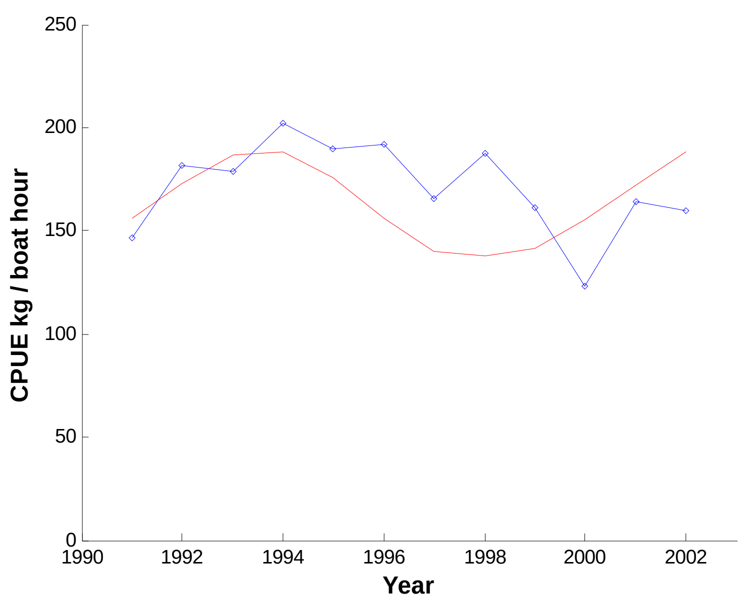


Figure 3.18 The surplus production model fit to the standardised CPUE.

Table 3.10 Summary of management parameters estimated from the surplus production model. (5:95%-ile) gives the 5 and 95 percentiles respectively. In the case presented the model was tuned to the standardised annual CPUE from the T4 managed area fishery. B_{2002}/K indicates the proportion of the year 2002 biomass relative to virgin biomass. $TAC_{0.1}$ is for the $F_{0.1}$ policy , and TAC_{msy} is for the F_{msy} policy.

Parameter	**Estimate**
$\mathbf{B_{2002}/K}$	0.19 (0.1:0.6)
$\mathbf{E_{MSY}}$	4092 (3552:21648)
$\mathbf{F_{MSY}}$	0.121 (0.049:0.327)
$\mathbf{F_{0.1}}$	0.109 (0.045:0.294)
$\mathbf{TAC_{msy,2002}}$	800 (328:2160)
$\mathbf{TAC_{0.1,2002}}$	720 (295:1944)

3.3.9 Prawn (T1) fleet trawl effort

The magnitude of prawn sector's stout whiting by-catch can be gauged by the number of T1 boat days of fishing effort. Since 1988 the annual level of the prawn sector's fishing effort had increased on the stout whiting fishing grounds from 5339 boat days to 9571 boat days in 1998 (Figure 3.19). The prawn sector's fishing effort in 2001 was 9082. Monthly effort levels were generally highest for the period November to April (Figure 3.20). What is interesting was the effect of the southern prawn trawl closure from 20th September to 1st November on monthly fishing effort in 2000 and 2001. Traditionally from 1988 to 1999 fishing effort in the months of October and November averaged 618 and 738 boat days respectively. In 2000 and 2001, the number of boat days fished in October dropped to 128 and 125 respectively, being deep water trawling (> 50 fathoms) only. However, in November 2001 fishing effort was well above the traditional average (1257 boat days). The spatial distributions of the prawn fleet fishing effort within the stout whiting managed area are shown in Figure 3.21.

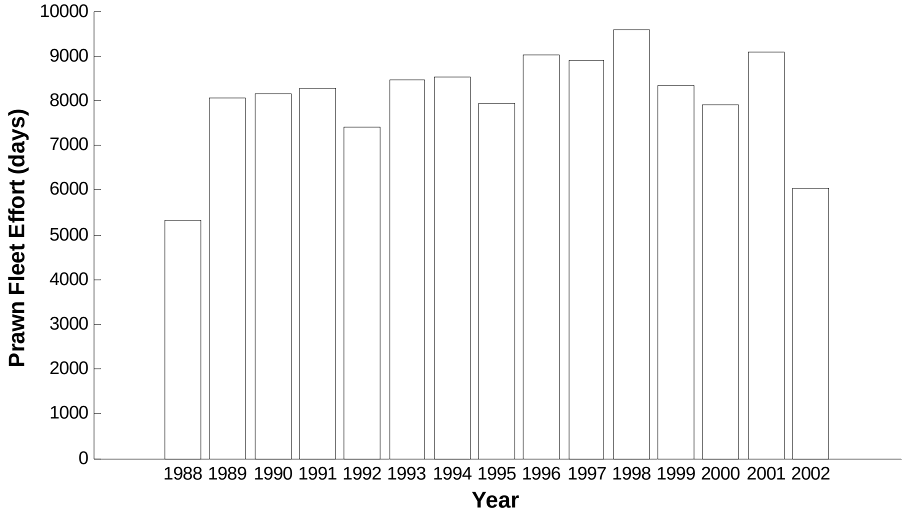


Figure 3.19 Annual prawn fleet effort (T1 total boat days fished) for the 30 minute logbook grids corresponding to the stout whiting managed area (grids - w32, x32, w33, x33, w34, x34, w35, x35, w36 and x36). The effort values exclude T4 licensed vessels. Effort reported for the year 2002 is only for January through to the southern closure in October (QFISH data entry of T1 effort in November and December was not complete as of February 2003).

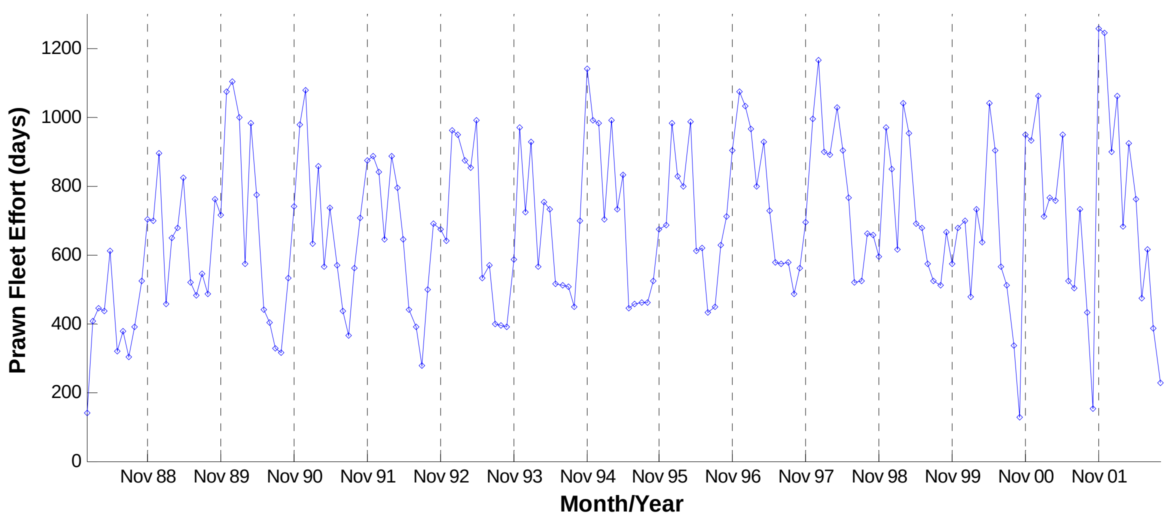


Figure 3.20 Monthly prawn fleet effort (T1 total boat days fished) for the 30 minute logbook grids corresponding to the stout whiting managed area (grids - w32, x32, w33, x33, w34, x34, w35, x35, w36 and x36; grid lines indicate the months of November). The effort values exclude T4 licensed vessels. Note the drop in October 2000 and 2001 fishing effort for the southern closure and the corresponding pulse in fishing effort after the closure in November.

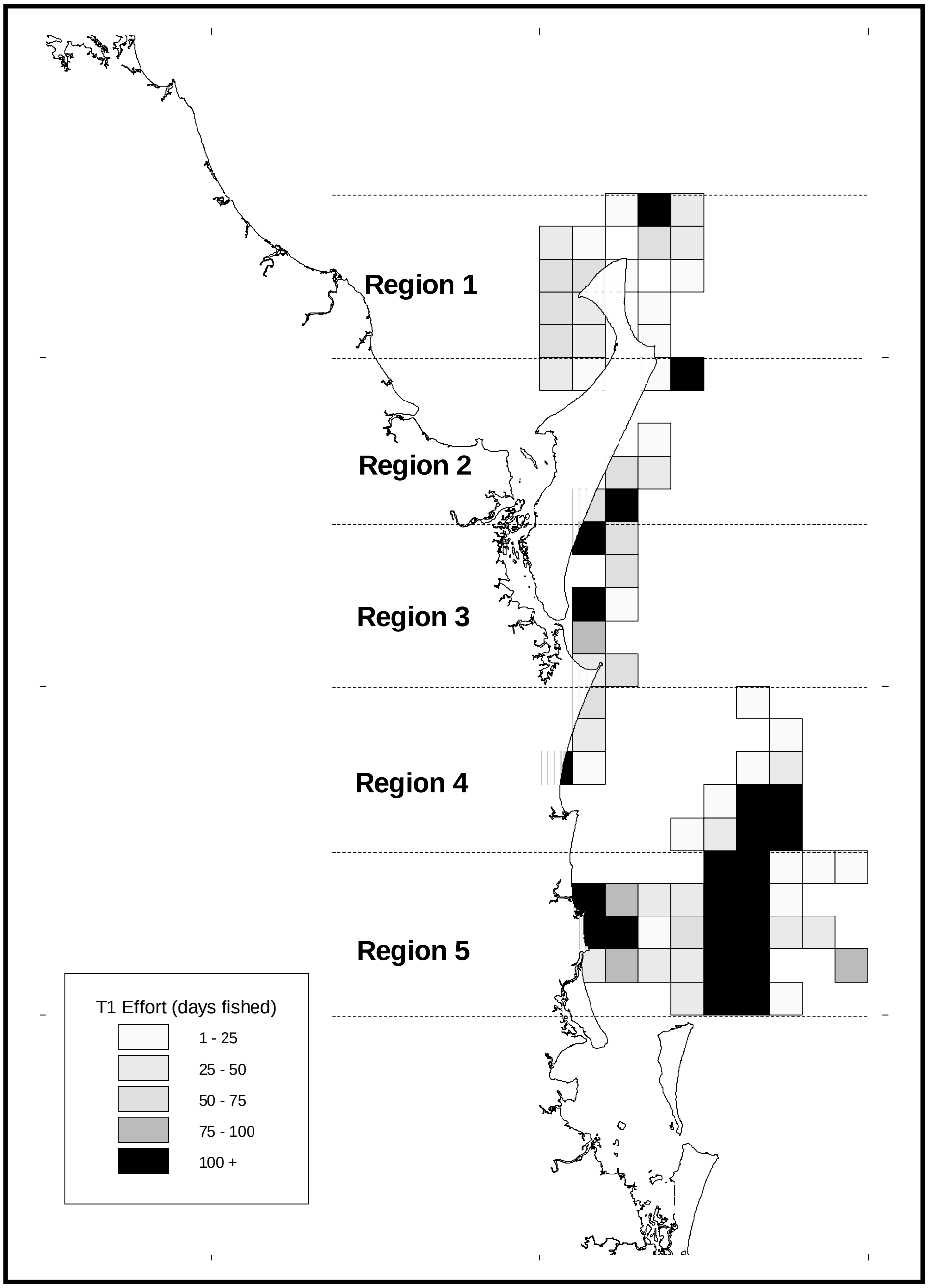


Figure 3.21 Spatial distribution of the 2002 T1 prawn sector effort in the stout whiting managed area. This figure includes only T1 fishing effort recorded to a spatial scale of 6-minute logbook grids, by at least five vessels in each grid.

3.3.10 The effects of bycatch reduction devices (BRD) in the eastern king prawn fishery.

3.3.10.1 Background

As a result of the changes brought about by the Queensland Trawl Fishery Management Plan and the federal *Environment Protection and Biodiversity Conservation Act 1999*, the Queensland trawl fishing industry is under increasing pressure to reduce the amount of bycatch that is generated by trawling. In the past, concern about bycatch was largely limited to the incidental capture of turtles. However there is increasing interest in the broader ecological impacts of trawling and as a result the concern now encompasses all species that make up the bycatch.

The precise total weight of bycatch produced by the Queensland trawl fishery is unknown. Logbook data indicate that 8,000-9,000 tonnes of scallops and prawns are landed annually but there is no comprehensive estimate for bycatch. Studies undertaken on different sectors of the fishery indicate that it is likely to exceed 25,000 t (see Robins and Courtney 1999, Stobutzki et al 2000).

There are two general approaches to reducing trawl bycatch; 1) reduce trawl fishing effort, and 2) adopt effective bycatch reduction devices (BRDs).

Turtle excluder devices (TEDs) and bycatch reduction devices (BRDs) are now compulsory throughout the Queensland trawl fishery (with the exception of certain areas). While the definitions and regulations for TEDs are well advanced, the guidelines for the design, installation and regulation of BRDs need to be improved. There are several different types of BRDs. Some of the more common devices that appear suited for the Queensland fishery include :

- radial escape sections,
- big eyes,
- fish eyes,
- square mesh panels or windows,
- composite square mesh panels and
- V-cuts or flappers.

Researchers from the Queensland Department of Primary Industries are measuring the effect that the devices have on both bycatch and on prawn and scallop catch rates, as part of a Fisheries Research and Development Corporation (FRDC) funded project. Measurements of the weight of the bycatch and weight of the targeted catch (prawns and scallops) are being obtained from about 1,000 individual net-trawls, which include measures from standard nets as well as those with TEDs and BRDs installed. About half (500) of the measurements will be obtained from commercial fishing vessels during their normal fishing trips with the other half (500) obtained by chartering commercial vessels to test different combinations of BRDs and TEDs.

Measurements are being obtained from the eastern king prawn, scallop and tiger/endeavour prawn sectors as these receive the highest levels of trawl fishing effort and are therefore likely to produce the largest amounts of bycatch. Similar information was collected from the Queensland banana prawn fishery from 1996-97.

At the completion of the project the results will be used to estimate the reduction in bycatch that has resulted from adopting BRDs and TEDs and to determine what effect they have on the catch rate of prawns and scallops. The Trawl Fishery Management Plan has put forward a Review Event that aims to reduce T1 bycatch by 40% by January 2005.

3.3.10.2 Methods

In October last year (2001) the first of the four planned charters was undertaken in the shallow water (< 50 fathoms) eastern king prawn sector. The commercial trawler, *Elizabeth G* was chartered with her crew to examine the effect of different combinations of TEDs and BRDs on the bycatch and catch rate of eastern king prawns. The results from the charter are provided below. Three other charters are planned for later in the year (2002) in the scallop, tiger/endeavour and deep water (> 50 fathoms) eastern king prawn sectors.

The charter was carried out from 10/10/2001 to 20/10/01 (10 nights). Measurements were obtained from 60 two-nautical mile trawls (Figure 3.22) in depths ranging from 19-86 m and located in areas that receive relatively high eastern king prawn fishing effort, as determined from the logbook database. In order to ensure the samples were representative of commercial catches and to avoid possible hook-ups, the precise location of each trawl was determined using pre-existing trawl track data provided by fishermen from their plotters.

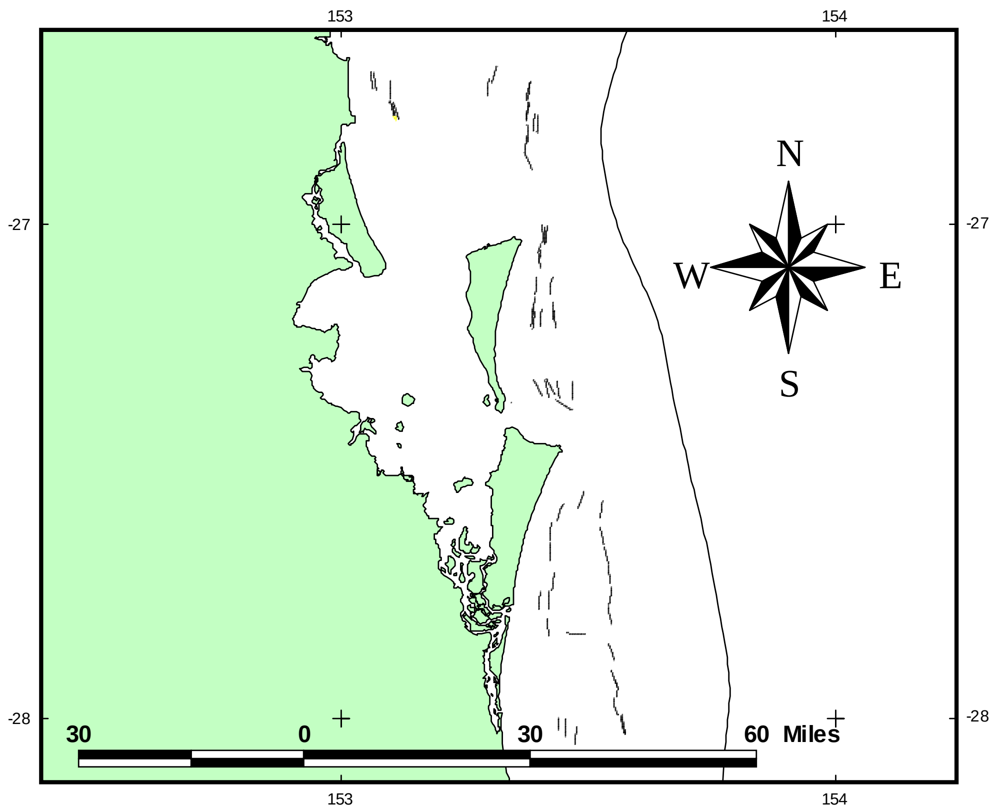


Figure 3.22 The location of the 60 two-nautical mile trawls off the southeast Queensland coast that were sampled to measure the effect of TEDs and BRDs on the catch rate of prawns and bycatch in October 2001.

Three 7-fathom Florida Flyer nets in triple gear configuration were used during the charter. This configuration is typical of the shallow water (< 50 fathom) eastern king prawn fishery. Although three nets were towed during each trawl, the TEDs and BRDs were only tested in the two outer nets (port and starboard), due to practical limitations. Catch rates from the stern net were not included in the study. Each trawl was undertaken along a relatively straight track so that the port and starboard nets swept equal areas along the bottom.

The BRD used throughout the charter was a radial escape section with the large meshes that allow fish to escape extending half way around the circumference of the net (Figure 3.23). This type of BRD was chosen because it is considered to be one of the more effective devices for reducing bycatch. The TED was a Wicks' TED and both the TED and BRD were sewn into the codends of the nets. After each two-nautical mile trawl the codends from the port and starboard nets were cut off and a different combination of TED and/or BRD was sewn back onto the net. This took about 25 minutes but was necessary to ensure that the different TED and BRD combinations were tested equally on both sides of the vessel.

Figure 3.23 The TED and radial escape section BRD that were tested during the 10-day charter in the eastern king prawn fishery in October 2001. The large meshes extend half way around the circumference of the net.

Trawl speed was approximately 2.3 knots and each trawl took about 50 minutes to complete. Six trawls were undertaken each night resulting in a total of 60 two-nautical mile trawls or 120 measurements (60 trawls x 2 nets) of bycatch and prawn catch rates over the 10 nights. Equal numbers of trawls were undertaken for each of the four possible combinations, as follows:

1. Standard 7-fathom net only (no TED or BRD) 30 trawls
2. Standard 7-fathom net with TED only 30 trawls
3. Standard 7-fathom net with BRD only 30 trawls
4. Standard 7-fathom net with both TED and BRD 30 trawls

Total 120 trawls

After each trawl the bycatch from each net was sorted and weighed. All prawns were retained and brought back to the QDPI Southern Fisheries Centre laboratory where each individual was sorted to species, sex and measured. Species such as three spot crabs, Balmain Bugs, pinkies, cuttlefish and octopus were weighed and recorded separately as "byproduct" and were not included in the weight of the bycatch. The bycatch only included those species that are typically discarded and returned to the water, such as rays, sharks, finfish and invertebrates that have no commercial value.

3.3.10.3 Stout Whiting Bycatch Results

There was a large amount of variation in the catch rate data that was attributed to differences between the 60 trawl locations. The depth and time-of-night also affected catch rates. In order to examine only the effects due to the different BRD and TED combinations, the between-location "noise" was statistically removed.

The effects of the radial escape section BRD were quite promising in reducing stout whiting caught in prawn trawls (Figure 3.24 and Table 3.11) and suggest that they can significantly reduce the weight of the bycatch. The analysis indicated that the differences between devices were statistically significant (Table 3.12).

The effects of BRD's and TED's on eastern king prawns catches were also examined. The numbers and size of eastern king prawns were converted to weights and the analysis examined the effect of the devices on the weight of the catch, rather than the number of prawns caught. Only eastern king prawns larger than about 45 count per pound (or larger than 10 grams) were included in the analysis because discussions with fishermen indicated that prawns smaller than this size are generally not retained. The results indicate that all combinations of the devices (TED only, BRD only and TED+BRD together) lowered the prawn catch rate. The largest decline occurred when the radial escape section BRD and TED were used together, resulting in a 16.9% reduction in eastern king prawns caught. When the TED only was used the prawn catch rate fell by 11.2% per net per two-nautical trawl. When the BRD only was used the catch rate fell by 8.3% per two-nautical trawl. The analysis indicated that the differences between the devices were statistically significant.

In brief, the results from this 10-day charter suggest that a radial escape section BRD used in conjunction with a TED have the potential to reduce stout whiting bycatch by about 60% in the shallow water (< 50 fathom) eastern king prawn fishery. However, this is likely to incur a loss of about 16.9% in marketable size prawns.

The charter went to considerable lengths to obtain prawn and bycatch catch rates that were representative of commercial fishing activities. For example, a commercial fishing trawler was used with 7-fathom Florida Flyers nets that are typical of this fishery. Furthermore, sampling was undertaken in an area that receives relatively high fishing effort and the location of trawls was derived using existing trawl track information.

The FRDC bycatch project is approximately halfway through to completion. Over the next 18 months additional charters and opportunistic sampling on board commercial vessels will continue.

Table 3.11 Average bycatch rates per 7 fathom net per two nautical mile trawl (BRD = radial escape design). Standard errors are shown in parentheses.

By-catch per 7 fathom net	No BRD or TED	TED	BRD	BRD and TED
Total Bycatch (kg)	44.1 (3.4)	37.2 (2.9)	34 (2.6)	31.8 (2.2)
Stout Whiting (kg)	4.5 (1.4)	3.0 (1.1)	1.5 (0.6)	1.7 (0.7)
Stout Whiting (numbers)	117 (37)	75 (28)	41 (18)	45 (18)
Ratio (kgs stout whiting to 1 kg eastern king prawns)	1.1 (0.4)	1.3 (0.5)	1.1 (0.6)	1.0 (0.4)
Stout Whiting Percentage of Total Catch (kgs)	7% (2.1)	6% (2.3)	4% (1.6)	4% (1.8)

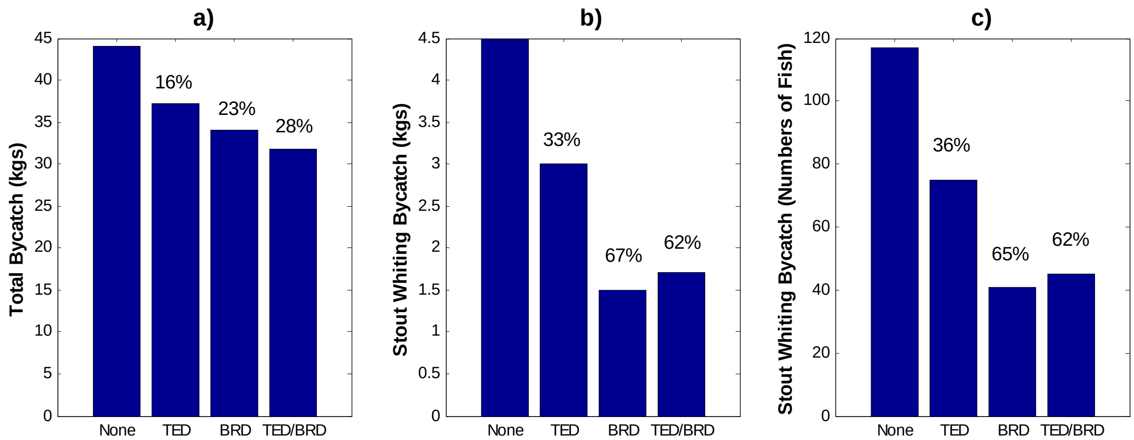


Figure 3.24 Comparison of the average bycatch rates taken per 7 fathom net per two-nautical mile trawl for a) total bycatch weight, b) stout whiting weight and c) stout whiting numbers. Percent reduction in bycatch from the standard prawn net (no BRD or TED = none) is shown on each bar graph. Thirty two-nautical mile trawls were undertaken for each codend type. The nets were 7-fm Florida Flyers. All of the trawling was located on commercial trawl fishing grounds in the shallow-water (< 50 fathoms) eastern king prawn fishery.

Table 3.12 Analysis of Variance (ANOVA) results for the effects of BRD and TED on total bycatch and stout whiting bycatch in prawn trawl nets.

By-catch	ANOVA statistics	Significant groupings and differences
Total Bycatch (kg)	df = 3,57; F = 15.27; p<0.001	None > TED > Radial Escape BRD > TED and BRD
Stout Whiting (kg)	df = 3,57; F = 2.26; p=0.091	(None = TED = Radial Escape BRD) > TED and BRD
Stout Whiting (numbers)	df = 3,57; F = 2.87; p=0.044	(None = TED) > (Radial Escape BRD = TED and BRD)

3.3.11 Comparison of QFS and SFC Databases

Up until 1999 two databases were being maintained on the stout whiting fleet. The database managed by SFC staff was more complete and was used for the assessments until 1999. The second database was managed by QFMA (now QFS) which records the catch and effort of the fleet using their logbook returns. In the past these data sets have often diverged markedly. The main reason was that the trawl logbooks required the catch to be recorded in kilograms, so this was only an estimate of catch as the fishers would not know their carton weights till the end of the season. The SFC database was in number of cartons and a weight multiplier was given at the end of the season. In 1999 a more suitable logbook was introduced for the stout whiting fishery (SW01 and later SW02). These log-sheets, entered by the QFS, were used in the 2000 assessment. Table 3.13 shows the difference between the 1999/2000 QFS (CFISH) and SFC databases. A high agreement between databases was achieved in 2000. The QFS (CFISH) database will be used in future assessments.

Table 3.13 Difference between the QFS (CFISH) and SFC database's. The 1999 comparison was for the recorded catch (t) between 1st April and 31st December from latitudes 24.5° to 27° (MA). The 2000 comparison was for the recorded catch (t) between 1st April and 30th June (MA).

Database	Catch (t)	Effort (hrs)	CPUE (kg/hr)
1999			
QFS	895 (12% under)	7908 (2% over SFC)	113
SFC (T4 and T1)	1020	7799	131
SFC (T4)	914	6492	141
2000			
QFS (T4)	226	1596 (1% under SFC)	142
SFC (T4)	227	1616	140

4. DISCUSSION

4.1 Analysis of stout whiting catches

In this report a generalised linear model (GLM) as described by McCullagh and Nelder (1989) was used. The analysis identified important factors affecting the stout whiting catch. Average catch rates were higher earlier in the fishing season, higher on the days leading up to the full moon, higher in shallower fishing depths within the managed area, and higher for boats using nets with larger mesh and longer sweeps. Further work is required annually to improve the accuracy of the GLM, as it is essential for future assessments. For this assessment inferences should be based on the standardised monthly catch-rates. A change in the coding to include individuals skippers has improved the accuracy of this analysis from last year.

4.2 Integrated Analysis

In this report an age-structured stock assessment model tuned to standardised monthly catch-rates and annual age-structures was used. This model design was based on methods described by Dichmont et al (2001), Haddon (2001) and Punt(1999b). The monthly time step model used a lognormal likelihood to estimate parameters on stout whiting catchability and recruitment. The model conformed to the assumptions that monthly catch rates were a reliable index of population abundance. The monthly age-structured model was more applicable, compared to the VPA and SPM models, as it captured the general within year pattern of fishing effort. The monthly model allowed for estimation of an average within year recruitment pattern of the stout whiting, and overall the analysis facilitated critical assessment of the fishery, thereby making more effective use of the catch and effort data, the annual fish aging data, and past biological work on the species. However, further enhancements to the model are required. For example, possibly using a spatial compartmental structure such as in Gordon (1994) to capture spatial dynamics of stout whiting; particularly if the spatial management area is to be reassessed. Further, and the most important, enhancement is to construct a stock recruitment curve for the species. This will reduce the uncertainty in projecting future implications of fishing on the stock, and optimise financial return from the fishery.

The Monte Carlo (Richards et al 1998) methodology used here was particularly applicable for evaluating possible quotas for the 2003 fishing-year, as the simulations allowed for adequate levels of uncertainty in all model parameters and catch data. Overall, the simulation facilitated critical assessment of the important levels of risk associated with, and yield that can be taken from the stout whiting fishery.

4.3 Virtual Population Analysis

Accepting that the upper and lower confidence intervals are still quite large on all estimates and that the model was very sensitive to the assumed value of natural mortality, the results of the VPA analysis suggests recruitment has declined in the last two years. However, if the most optimistic values for total biomass and recruitment are used (ie. the upper 95% confidence intervals), the declining trend in recruitment may not be that strong. Even though, four points need to be emphasised:

- The analysis is based on the need for accurate fish ages. In the last two assessments there has been a concern about the readability of stout whiting whole otoliths. Comparison of age readings between present and earlier readers showed large discrepancies. This was in contrast to the preferred whole otolith readings recommended by Butcher and Brown (1995). This issue is a major concern for the accuracy of the age based stock assessment. Improved age verification is needed to ensure the VPA gives accurate population assessments and trends. This year aging protocols were developed to guide readers and additional work was funded by the Queensland Fisheries Service to verify the accuracy of aging whole stout whiting otoliths. Additional work is still required to verify pre 2001 fish aging.
- The data set is still very small to estimate absolute abundance without fears of bias, and
- The additional T1 gear stout whiting catch from other areas were not included in this analysis.

4.4 Surplus Production Model

The surplus production model did not fit the observed annual average CPUE data well. This was due to the high variability of the observed CPUE in the last five years. The model was affected by the initial CPUE increase in the first four years. In the later years (1996-2002) the CPUE varied by about 30% between years. Due to this variation, the model estimate of carrying capacity (K) had to be restricted within a prior distribution of between the year 1990 biomass and 20,000 tonnes. Overall, management parameters indicate that the resource is still over-exploited (the B_{2002}/K ratio from using the standardised CPUE was estimated to be less than 0.2). Discussions on the 2003-fishing season TAC should consider the variation in results from all three models (there is great uncertainty in all models). This surplus production model will be dropped from future assessments.

4.5 Resource status and suggested TAC

- The 2002 industry agreed TAC was 1000 tonnes
- The 2002 catch was 855 tonnes.
- This assessment of the stout whiting stock does not include the portion of the stock caught as by-catch by prawn trawling. Nor does it assess the stock of whiting occurring outside the designated managed area.
- The accuracy of fish aging is uncertain.

- The short time-series and the inherent variability of data used in this assessment decreased the confidence that we can place in our estimates.
- The integrated age-structure model conforms to the assumption that monthly catch rates were a reliable index of population abundance.
- The VPA assessment is very sensitive to the assumed value of natural mortality (M).
- All of the TAC estimates are reasonably consistent in the 700 to 900 t range. Given the stock assessments high uncertainty, any increase in TAC above 1000 t has high risk. The management strategy evaluation (MSE) table should be used to guide decisions on the 2003 TAC setting and to understand how best to compromise the issues of risk (over fishing) and optimising yield (maximising catch and value in the fishery). In the last four years total catch has varied between 1178 t and 498 t. This year's assessment has shown a decrease in recruitment and biomass after the catch levels of 881 t in 2001 and 855 t in 2002. The limit reference point of B/K is at about 0.2-0.4. Any increase in catch above 1000 t will reduce future recruitment.
- Additional work on fish aging and the new integrated age-structured model (including data on the T1 prawn sectors bycatch of stout whiting) is required for next year.

4.6 Prawn (T1) fleet trawl effort

The magnitude of the prawn trawl sector's total by-catch of stout whiting is unknown. This creates uncertainty about determining the status of the stout whiting stock and limits the quality of management decisions in setting accurate quota limits. From the QFISH logbook system we have an estimate of fishing effort for the prawn fleet, but no information on stout whiting by-catch exist. Southern Fisheries Centre is currently documenting by-catch in the eastern king prawn sector. Information from this FRDC funded project may provide valuable catch rate data to estimate the total by-catch of stout whiting. However, the data collection is expensive and is limited seasonally and spatially. The amount of fishing effort by the prawn sector within the stout whiting management area is significant. The effect of this effort on the stout whiting fishery needs to be determined. Compulsory uses of by-catch reduction devices by T1 vessels were introduced in December 2000. In this report we have quantified the effectiveness of radial escape BRD's and TED's in reducing stout whiting bycatch from eastern king prawn trawls. However, more data is required to test other BRD designs and to estimate stout whiting bycatch rates in the T1 prawn sector.

The level of prawn trawling effort and catch rates within and outside the stout whiting managed area needs to be estimated to improve the accuracy of future stock assessments. If the total by-catch of stout whiting can be estimated, stout whiting and eastern king prawn stock assessments should be viewed in parallel to optimise management strategies for both fisheries. This is especially important since the prawn sector effort levels (November to April) partially overlap with the spawning period of stout whiting. The pulse of prawn fishing effort in November 2000 following the southern closure may be a concern for a number of fishery resources.

4.7 Future considerations

4.7.1 Data

The accuracy of the recorded stout whiting catches in the QFS database was much improved this season. However, a number of issues still need to be addressed before next season. These issues are:

- Inconsistencies in fishing depths. The data entry screen needs to be changed so that all depths are entered as fathoms.
- Skipper identification needs to be consistently entered so manual checking is not required.

Important – Stout whiting log-sheets from two vessels had recorded daily data only. Shot by shot data is required for the catch rate analysis. Fishers need to be reminded to have log-sheets sent in by the 15th January.

4.7.2 Stock assessments

The options are to either continue as present (no additional work) or to improve the assessment models. The following needs to be considered, otherwise the same uncertainty around TAC estimates with be produced each year.

AFFS staff within the Southern Fisheries Centre are available to improve the models in the assessment. The statistical analysis of catch rates (GLM) requires about one week of time to re-assess. About one month is required in the next year to improve the stock assessment models in Matlab. Mr O’Neill currently completes the stock assessment of the stout whiting fishery at a direct cost to DPI-AFFS.

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6. APPENDIX

6.1 History of stout whiting catches

Table 6.1 Summary of stout whiting catch and effort by T4 endorsed vessels with different combinations of gears, areas and time of year. Note that the summary column highlights the shift of the T4 endorsed vessels' catch from using sweeps only to sweeps and prawn gear. In 2000 the fishery legislation was strictly enforced to limit stout whiting catches to T4 gear only.

		1 January – 31 March				T4 season (1 April – 31 December)					
	Summary	Management Area (Prawn gear)		Other areas (including Gold coast)		Management Area (Sweeps)		Management Area (Prawn)		Gold Coast (prawn)	
Year	Sweep T4 Catch / Total Catch (%)	Catch (t)	Effort (hrs)	Catch (t)	Effort (hrs)	Catch (t)	Effort (hrs)	Catch (t)	Effort (hrs)	Catch (t)	Effort (hrs)
1991	94.1	32.7	248	0	0	528.4	3613	0	0	0	0
1992	100	0	0	0	0	893.4	5736	0	0	0	0
1993	72.4	211.3	977	0	0	1000.3	5242	0	0	170.4	Unknown
1994	83.8	15.3	234	0	0	1958.2	10330	0	0	362.4	1549
1995	82.2	112.3	1040	0	0	1964.8	9806	0	0	313.5	1052
1996	93.9	17.4	277	91.8	918	2226.6	12577	0	0	36.1	257
1997	68.4	3.7	81	103.4	1437	1402.7	10902	0	0	541.6	3453
1998	68.4	25.4	304	257.1	2039	1073.6	5560	204.3	1756	0	0
1999	72.9	157.3	1132	0	0	913.5	6492	107.3	1307	0	0
2000	100	0	0	0	0	497.1	4391	0	0	0	0
2001	100	0	0	0	0	880.6	5622	0	0	0	0
2002	100	0	0	0	0	855	5174	0	0	0	0

6.2 Outline of stout whiting catch sampling (Important for Fishers)

The stout whiting fishery monitoring and assessment has been undertaken for twelve years now. However, the fishery has changed in many aspects over time and these changes have not yet been accommodated into the assessment program. The outcome of the stout-whiting meeting held in March 2001 was the concern expressed from the fishing industry members about the data inputs into the stock assessment models. The main problem highlighted was that the catch size/age composition of stout whiting had changed in the last two years as a result of the change in market demand for larger fish. Therefore, some operators have actively targeted larger sized fish. It was also highlighted that the mesh sizes used and maybe even other fishing gear are different between fishing vessels. These differences may also alter the catchability of stout whiting between vessels and therefore bias the size/age composition of the catch and catch rates.

Under the headings below I have outlined the catch-sampling scheme and the vessel standardisation information required for 2001.

6.2.1 2003 catch sampling

Southern Fisheries Centre will contact each vessel to arrange the collection of catch samples. These catch samples will consist **of 2 5kg boxes collected each fishing trip** from each vessel and is outlined as follows:

- 1 box collected from night trawl shots.
- 1 box collected from early morning trawl shots.

These boxes will be collected randomly from all boats. The boxes taken from each vessel should contain a **random/representative sample of fish** caught in the trawl shot. If the catch is usually sorted into small and large fish, then the catch sample provided for the DPI stock assessment should be **taken before any catch sorting (very important)**.

6.2.2 Vessel standardisation

The collection of vessel changes associated with the fishery has been incorporated into this year's stock assessment. Vessel performance in the fishery can change from year to year due to upgrades to different technologies such changes to skippers, vessel motors, propellers and even changes to different components of the fishing gear. This creates uncertainty as to how well our current estimates of catch rates reflect the status of the stout-whiting fishery.

To address this, we need to collect information on changes in the fishing ability of each vessel. The results will then be used to adjust catch rates for differences between vessels over time. This will improve the accuracy of the stock assessment. To do this, a questionnaire will have to be completed for each vessel in the 2003 fishery. A person from Southern Fisheries Centre will speak to each vessel owner about this later in the year.

6.3 Stock Structure of Stout Whiting

6.4 Stout Whiting Sampling – information sheet for your vessel

DPI catch samples will consist of two 5kg boxes collected each fishing trip from the fishery and is outlined as follows:

- 1 box collected from evening trawl shots.
- 1 box collected from early morning trawl shots.

The more fishing trips competed each month the more boxes collected. Southern Fisheries Centre will contact each vessel every month to arrange the collection of these catch samples and logbooks. If you need to phone us about samples, our contact number is 3817 9595 (ask for Ian Breddin or Eddie Jebreen).

Very important !

The catch boxes taken for DPI should contain a **random/representative** sample of fish caught in the trawl shot. **The DPI catch sample should be taken before any catch sorting (ungraded).** If the catch is usually sorted into small and large fish, then the catch sample provided for the DPI stock assessment should be taken before any catch sorting **(very important)**.

If you sort your stout whiting catch and discard the small sized fish, please record the information in the logbook. This additional information will help DPI interpret the annual assessment results. For each trawl shot record the –

- number of cartons of stout whiting discarded from the shot.
- size of carton eg 17 kg
- size of fish eg less than 25g

Also, in your logbooks remember to **record any zero catches**.

Thankyou for your effort.