Gulf of Carpentaria Finfish Trawl Fishery

Maximum Sustainable Yield

Saddletail snapper: *Lutjanus malabaricus*.

Queensland Government

This publication has been compiled by GM Leigh and MF O'Neill of Agri-Science Queensland, Department of Agriculture and Fisheries.

Summary

The Gulf of Carpentaria Finfish Trawl Fishery operates under developmental permits and harvests five main tropical snapper species. The fishery operates in eastern Gulf of Carpentaria waters and is managed by Fisheries Queensland on behalf of the Queensland Fishery Joint Authority. For the years 2004–2014, the fishery Total Allowable Commercial Catch (TACC) was fixed at 1250 t and substantially under-filled. In 2011 new stock analyses were published for the fishery. Results were presented to industry including the estimated equilibrium maximum sustainable yield (MSY) of 450 t for east Gulf of Carpentaria waters. The MSY value represented the maximum average combined species harvest that can be taken long-term; combining MSY harvests of the five main species. For the 2015 calendar year, a revised 450 t harvest quota was set for Crimson Snapper, Saddletail Snapper, Red Emperor and other Emperor species; plus a tonnage allowance for other permitted species. The revised quota tonnage represented a considerable reduction from the 1250 t set in previous years. Industry raised questions about not understanding how the MSY was arrived at and why it was less than early 1990s yield estimates. The purpose of this report is to explain the MSY estimates for east Gulf of Carpentaria waters. The 450 t MSY represents at present the best estimate available and is consistent with pre-2011 estimates.

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Background

The Gulf of Carpentaria Developmental Finfish Trawl Fishery (GOCDFFTF) harvests five main species from the fish family Lutjanidae: Crimson Snapper (*Lutjanus erythropterus*), Saddletail Snapper (*L. malabaricus*), Red Emperor (*L. sebae*), Golden Snapper (*L. johnii*) and Mangrove Jack (*L. argentimaculatus*). Lesser but important harvests are also taken of the Emperor species (Lethrinidae) and Goldband Snapper (*Pristipomoides multidens*). The fishery operates in eastern Gulf of Carpentaria waters and is managed by Fisheries Queensland, within the Department of Agriculture and Fisheries on behalf of the Queensland Fishery Joint Authority. The fishery operates under developmental permits, with three vessels granted access to the fishery in 2015.

For the years 2004–2014, the GOCDFFTF Total Allowable Commercial Catch (TACC) was fixed at 1250 tonnes (t) for Crimson Snapper, Saddletail Snapper, Red Emperor and other Emperor species (for more detail see: GOCDFFTF developmental permit conditions). The TACC was based on report findings (Ramm 1994; Ramm 1997a; Ramm 1997b; Sainsbury 1990; Sainsbury, Campbell *et al.* 1991) and management committee interpretations of stock survey and modeling results from the early 1990s. The TACC evolved from a limited yield-per-recruit analysis scaled by the 1990 survey estimate of tropical snapper biomass (called all large *Lutjanus* species in: Sainsbury, Campbell *et al.* 1991). For the whole of Gulf of Carpentaria, a sustainable yield of about 3000 t of all large *Lutjanus* was used as a basis by management. This value was divided by two for the eastern gulf, with the GOCDFFTF TACC set equal to 1250 t and 250 t kept by management and industry in reserve. A summary of GOCDFFTF fishery harvests to compare against the TACC is provided in Table 1.

In 2011, data analyses and stock modelling were published for tropical snappers in northern Australian fisheries including the east Gulf of Carpentaria fishery (O'Neill, Leigh *et al.* 2011). Standardised catch rates (1998–2009) were used as indicators of abundance and calculated to assist understanding of the variability in the data and catch trends. Trawl catch rates of tropical snappers from eastern Gulf of Carpentaria waters varied between years and were below their long-term average in the last three years (2007–2009). Fish age frequencies between 2004 and 2006 showed significant age truncations, but may provide misleading impressions of high fishing mortality because of the low effective samples sizes of the data, as a result of the spatial effect of fish schooling by age (O'Neill, Leigh *et al.* 2011). The stock modelling concluded that the Gulf of Carpentaria snapper populations were not overfished. The exploitable biomass for Gulf of Carpentaria waters was estimated to be greater than 40% of unfished biomass ($B_{2009}/B_{1945} > 0.4$). Declines in 2007–2009 exploitable biomasses corresponded with the increased harvests.

Results from the O'Neill, Leigh *et al.* (2011) research were presented to industry at three face-to-face meetings held in Brisbane on 14 March 2011, 24 July 2014 and 9 October 2014. Included in the results was the estimated equilibrium maximum sustainable yield (MSY) of 450 t for east Gulf of Carpentaria waters. The MSY was calculated at the request of Fisheries Queensland using the stock model developed as a part of FRDC Project No. 2009/037, 'Sustaining productivity of tropical snappers using new monitoring and reference points' (O'Neill, Leigh *et al.* 2011). The MSY value represented the maximum average combined species harvest that can be taken long-term; combining MSY harvests of the five target species. At the meeting on 9 October 2014, industry raised questions about not understanding how the MSY was arrived at and why it was less than previous yield estimates (Sainsbury, Campbell *et al.* 1991). The purpose of this report is to explain the MSY estimates for the GOCDFFTF (east Gulf of Carpentaria waters).

For the 2015 fishing year, a 450 t harvest quota (TACC) was set for the GOCDFFTF by Fisheries Queensland. The TACC was allocated to the three permitted vessels. The TACC was based on a species combined estimate for MSY (for the five key species listed above).

Table 1. Annual fishery statistics for the GOCDFFTF in 2004–2015; no fishing was conducted by permit holders in 2014.

Feature	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total harvest all *spp.* (t)	371	478	613	558	755	745	607	626	69	25	0	218
Total effort (days)	237	225	292	326	390	361	330	326	39	7	0	55
Permits (active)	2	2	2	4	4	4	4	4	3	1	0	2
GVP (A$ million)	2.2	2.9	3.9	3.7	4.9	4.9	4.0	4.1	0.5	0.2	0	1.4
Harvest totals for the target species (spp.)												
Crimson snapper (t)	143	178	237	239	328	343	275	249	29	12	0	100
Saddletail snapper (t)	59	76	171	187	225	230	190	224	21	9	0	67
Red emperor (t)	<1	2.5	2.9	3.2	9.8	11.5	5.7	8.2	3.4	<1	0	1.5
Golden snapper (t)	27.6	21.3	31.5	18.5	25.2	20	22.7	30.6	2.4	<1	0	5
Mangrove jack (t)	48	74	71	58	54	50	40	32	3	<1	0	12

Objectives

The purpose of this report is to explain:

1. how the 450 t MSY estimate for the east Gulf of Carpentaria was determined
2. why the estimated MSY is lower than early yield estimates
3. how the reduction in GOCDFFTF TACC is consistent with increasing fishing effort in the Northern Territory and a 'sustainable' stock status determination for the northern Australian stocks of *Lutjanus malabaricus* and *L. erythropterus*
4. what data are required to improve accuracy of TACC estimation.

The report provides responses against the objectives for eastern Gulf of Carpentaria waters managed by Fisheries Queensland.

Methods

This section describes the fish trawl survey conducted in the Gulf of Carpentaria by CSIRO in 1990 (pages 7-8, Sainsbury, Campbell *et al.* 1991) and the stock model used to estimate the most recent MSY for the Gulf of Carpentaria (FRDC Project 2009/037: O'Neill, Leigh *et al.* 2011). The trawl survey formed the basis for early yield estimates (pre-2011).

Biomass survey

Between 21 November and 12 December 1990, the CSIRO Division of Fisheries carried out a survey of tropical snappers (called 'large *Lutjanus*' in the survey) in the Gulf of Carpentaria and the Australian Fishing Zone to the north. The objectives were to determine the distribution of demersal fish fauna and benthos across the Gulf of Carpentaria and thus the survey had a systematic design with a sampling unit of 30 by 30 nm (Figure 1). Note that this type of systematic survey may be suitable for investigating distributions of species, but a random survey design is more appropriate for the estimation of tropical snapper biomass (see page 14). The survey extended from 136.5º E to 141.5º E in water depths of 20 to 85 m. At 106 stations, a 28 m Frank and Bryce trawl was fished for 30 mins at a speed of around 3.3 knots. All fish taxa were identified, counted and weighed. The distributions of catch weights of Saddletail Snapper and all tropical snappers combined (corresponding to the five main species in the GOCDFFTF) in the survey area were analysed for a range of trawl retention and effective trawl widths. Biomass population estimates were calculated by expanding fish densities (kg/km^2) up to the assumed total survey area and pre-1991 fishing areas in the Gulf of Carpentaria.

Figure 3.d.ii.1. Grids sampled in the 1990 CSIRO trawl survey.

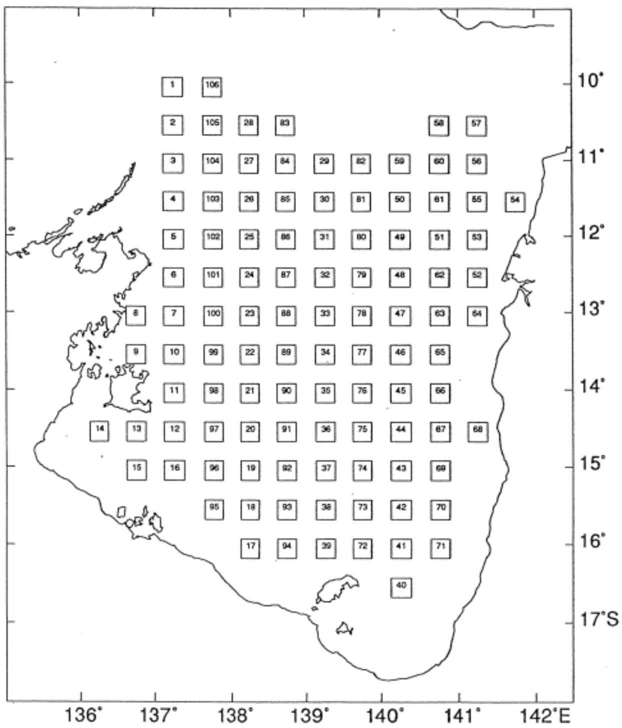

Figure 1. The 106 grid locations sampled by CSIRO in 1990. Note: grids 1–3, 104–106, 28 and 83 belong to the Arafura Sea fishing zone (region 4 in the FRDC 2009/037 stock model, Figure 3c), not the Gulf of Carpentaria. This was not adjusted for in the survey biomass estimates for the GOC (Sainsbury, Campbell et al. 1991).

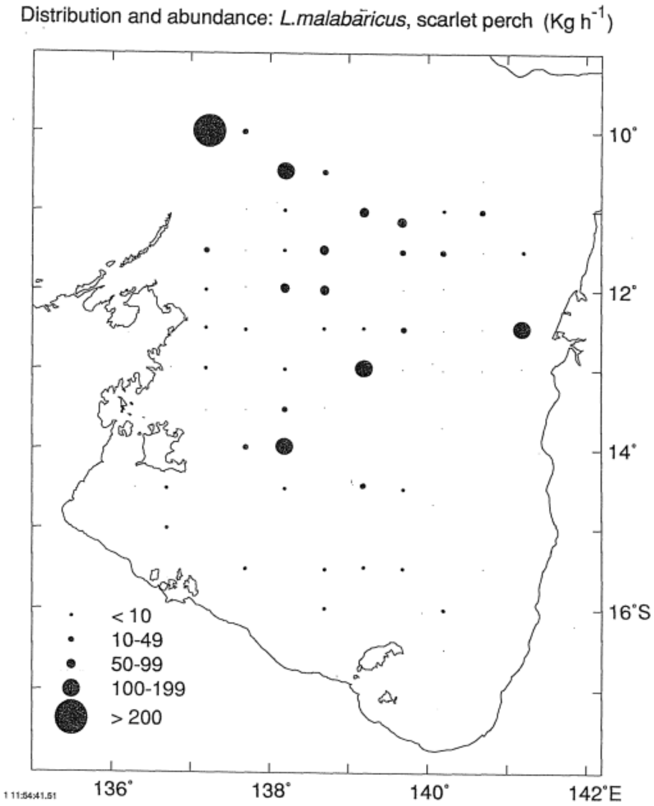

Figure 2. Spatial bubble plot of Saddletail Snapper catch rates from the survey. Note the high catch rates taken from survey sites 1 and 28, located outside the Gulf of Carpentaria region (Sainsbury, Campbell et al. 1991).

Stock model

Available data consisting of harvest tonnages, standardised catch rates and age-frequency samples, were used as inputs to an annual, age-structured population dynamic model which covered six species across six regions (Figure 3). The six regions were:

1. Queensland Gulf of Carpentaria, inshore
2. Queensland Gulf of Carpentaria, offshore (Figure 3e)
3. Northern Territory Gulf of Carpentaria (inshore and offshore combined; Figure 3d)
4. Northern Territory Arafura (Figure 3c)
5. Northern Territory Timor (Figure 3b)
6. Western Australia Kimberley (Figure 3a).

The separation of the Queensland Gulf of Carpentaria into Regions 1 and 2 was undertaken because it was of interest to Fisheries Queensland, especially with regard to Mangrove Jack, a species which tends to inhabit inshore areas in its juvenile phase and then move offshore. The MSY estimate was for Region 2 Queensland Gulf of Carpentaria offshore (Figure 3e), which covers the GOCDFFTF fishing grounds (>20 m water depths; Figure 4).

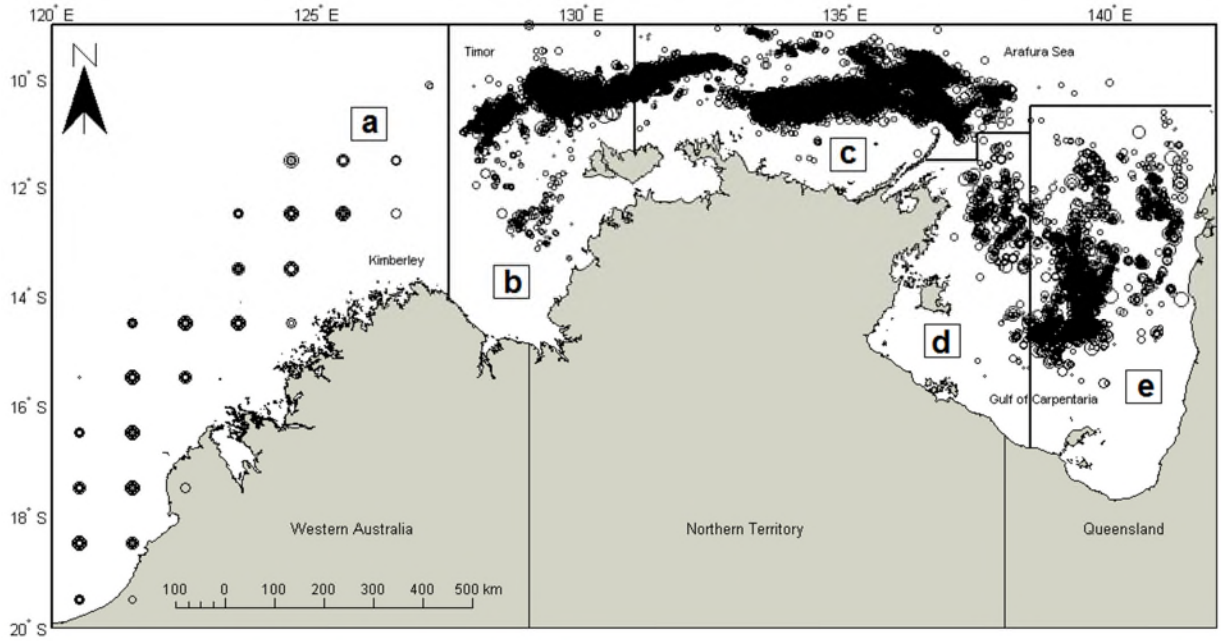

Figure 3. Spatial distribution and stratification of recorded commercial tropical snapper harvests. The Northern Australian fisheries were stratified from west to east as: a) Northern Demersal Scalefish fisheries off the north-west coast of Western Australia (Kimberley sector); b) Timor Reef Demersal and adjacent southern fisheries (Timor sector); c) Arafura Sea Demersal and Trawl fisheries (Arafura Sea sector); d) western Gulf of Carpentaria Demersal and Trawl fisheries (west Gulf of Carpentaria sector;, and e) eastern Gulf of Carpentaria trawl fishery (GOCDFFTF sector). The data represent commercial logbook records between 2003 and 2009. Fishing methods were line, trap and trawl. The area of each circle marker was determined by kilograms of harvest. Harvest includes the key Lutjanidae species.

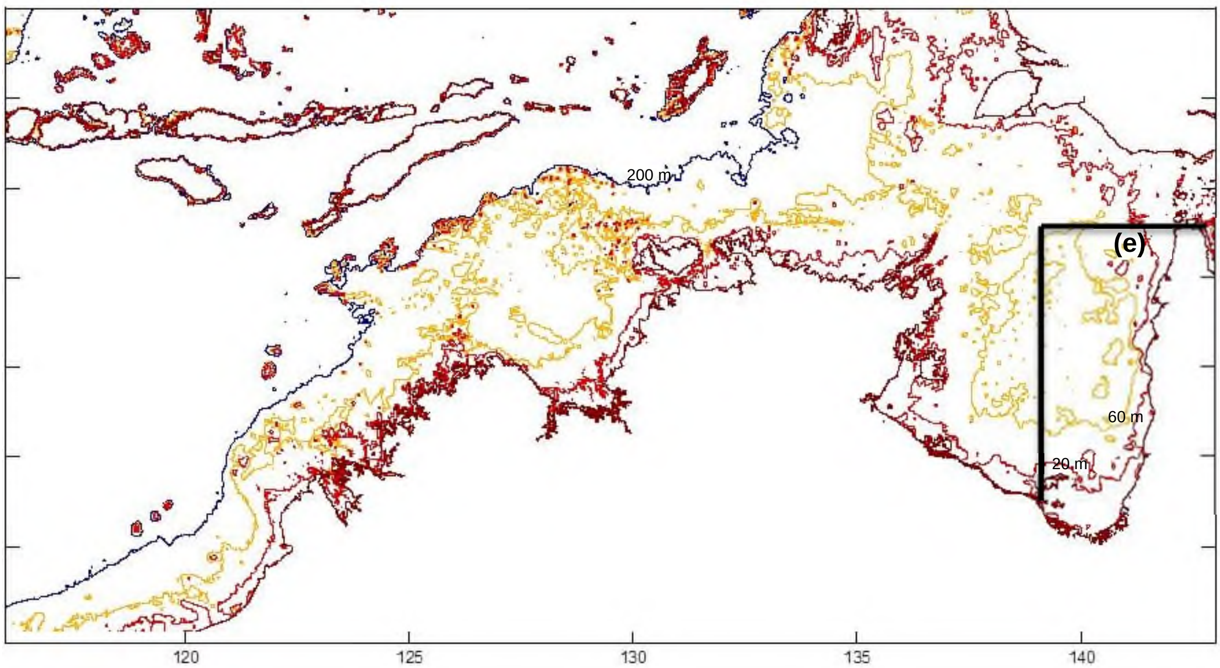

Figure 4. Depth contours for northern Australia. The map outlines the coast line, plus 20 m, 60 m and 200 m contours, and Region 2 Queensland Gulf of Carpentaria offshore (e).

Not all species in all regions were of interest to each fishery management agency. The following region–species combinations were identified and were included in the model:

- GoC (Qld and NT): *L. erythropterus*, *L. malabaricus*, *L. sebae*, *L. johnii*, *L. argentimaculatus*
- NT Arafura: *L. erythropterus*, *L. malabaricus*, *L. sebae*, *L. johnii*, *P. multidens*
- NT Timor Reef: *L. erythropterus*, *L. malabaricus*, *L. sebae*, *P. multidens*
- WA Kimberley: *L. sebae*, *P. multidens.*

The population dynamic model included a 'tuning' phase to fit the model to reconstruct the data (standardised fish catch rates and observed fish age-frequencies). The tuning phase included estimation of the following key parameters used to calculate MSY:

- Deterministic stock-recruitment parameters: the model used the Beverton-Holt stock-recruitment relation, which estimates the number of recruits that are contributed to the population based on the number of spawning adults in the population (i.e. stock productivity).
- Instantaneous natural mortality rate *M*; a separate value was estimated in the model for each species, inferred mainly from regional age-frequency data.
- Vulnerability parameters, which estimate the vulnerability to fishing of each age group in the population.

The model was tuned by Markov Chain Monte Carlo (MCMC), a mathematical method by which a large sample of different values of the parameters was generated in order to show the range of potential outcomes. The major advantage of MCMC was that the sampled combinations of parameter values can be reused to simulate different projections of population status and MSY.

The key parameters listed above were used to construct a possible range of tonnages for virgin exploitable biomass (B_0). The main reason for using B_0 is that the values can be compared to fishery-independent trawl surveys (Ramm 1994; Sainsbury, Campbell *et al.* 1991).

The model was programmed in a technical computing language and included a graphical user interface for the user to set values of parameters (Figure 5).

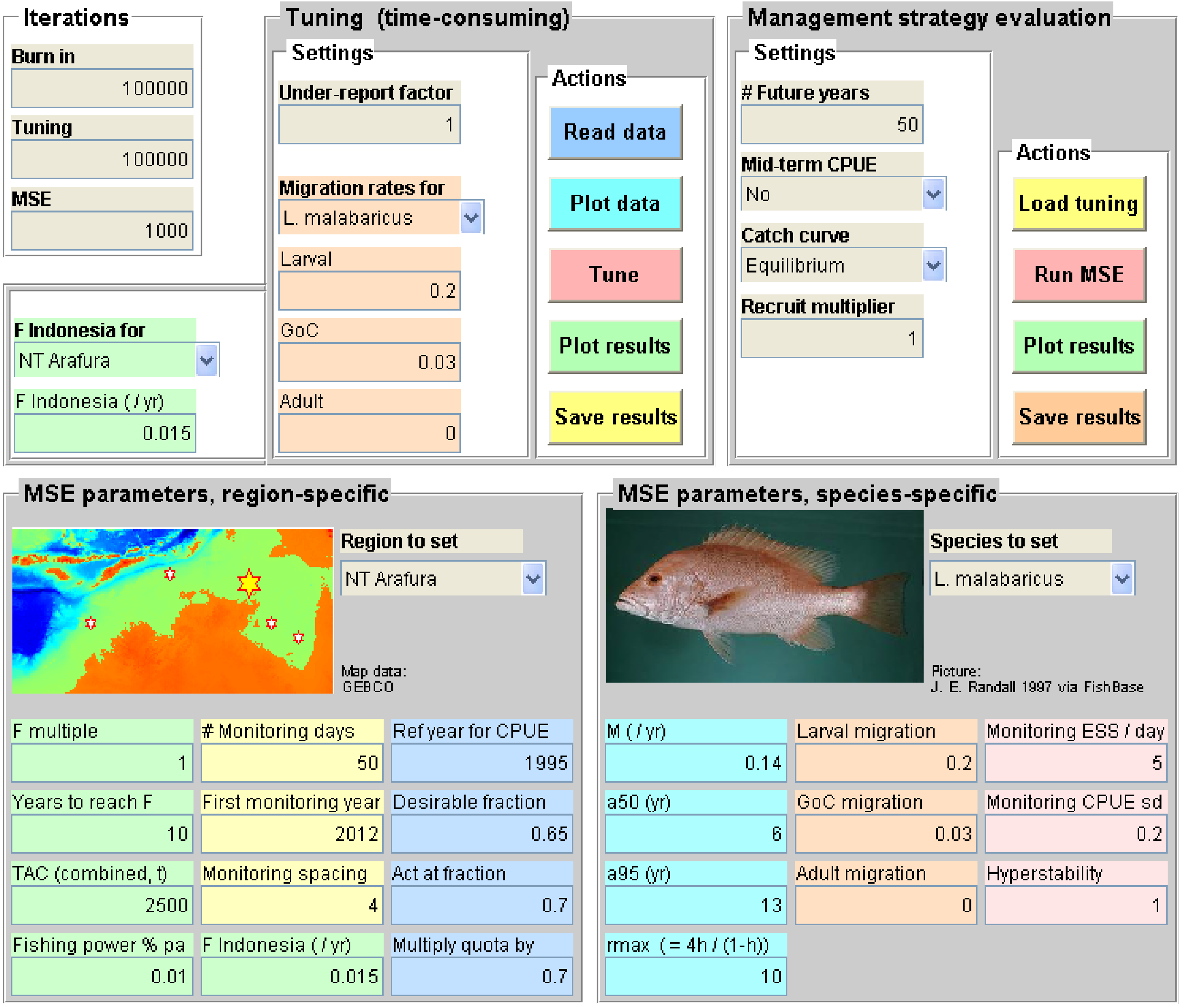

Figure 5. Picture of the graphical user interface for the population modelling.

Results and discussion

How was MSY determined?

Maximum sustainable yield (MSY), for all five species combined in Queensland Gulf of Carpentaria waters, was calculated using the estimates of virgin exploitable biomass B_0 from the FRDC stock model tuning (Table 2). The two quantities MSY and B_0 are strongly correlated, meaning that the major source of uncertainty in MSY is actually uncertainty in B_0. Theoretically, fishing at MSY reduces the biomass to around 35–40% of B_0 (denoted as B_{40}). The fishing harvest rate at MSY is approximately equal to the natural mortality, which is around 15% per year for long-lived species such as tropical red snappers (Table 10, page 54 of the FRDC report; (O'Neill, Leigh *et al.* 2011). This equates to an annual harvest of roughly 6% of B_0 assuming the population is stable. As fishing progresses, with a constant TAC of 6% of B_0, the population will be fished down and the harvest rate will approach 15% of the fished-down biomass (B_{40}). For example, using an exploitable B_0 rounded up to about 7500 t for all five species combined in Queensland Gulf of Carpentaria waters, then a 6% fraction of this biomass equated to about 450 t (Table 2). Approximate TACC tonnages for other species can be calculated following this process for all fishing regions in northern Australia.

Table 2. Approximate maximum likelihood estimates of exploitable virgin biomass (B_0) from the stock model tuning, for species of interest in each region. Approximate MSY estimates are also shown as 6% B_o. Estimates are subject to uncertainty due to the lack of data to inform B_0.

Region	Species	B_0 (tonnes)	Total B_0 (t)	6% B_0 (t)
Qld GoC	*L. erythropterus*	2820	7180	430
	L. malabaricus	2500		
	L. sebae	350		
	L. johnii	1010		
	L. argentimaculatus	500		
NT GoC	*L. erythropterus*	2060	3680	220
	L. malabaricus	1200		
	L. sebae	120		
	L. johnii	110		
	L. argentimaculatus	190		
NT Arafura	*L. erythropterus*	5510	37340	2240
	L. malabaricus	27590		
	L. sebae	1040		
	L. johnii	560		
	P. multidens	2640		
NT Timor Reef	*L. erythropterus*	580	9000	540
	L. malabaricus	3160		
	L. sebae	370		
	P. multidens	4890		
WA Kimberley	*L. sebae*	8400	12040	720
	P. multidens	3640		

Why is the 2014 MSY lower?

The first yield estimates for tropical snappers were calculated by the NFRC (Sainsbury, Campbell *et al.* 1991). They compared estimates using different methodologies: the trawl survey biomass estimate (calculated by expanding fish densities kg/km^2 up to the assumed total survey area); a surplus production model using all available catch and effort data to estimate stock production and biomass; and a yield per recruit analysis to estimate a $F_{0.1}$ fishing harvest rate fraction and then multiplied by a biomass estimate. The fishing harvest rate $F_{0.1}$ is a value slightly less than the F-value that would maximise yield if the number of new, young fish entering the population were unaffected by fishing (http://www.fao.org/docrep/006/X8498E/x8498e0c.htm).

Table 3 summarises historic yield estimates of tropical snappers for the Gulf of Carpentaria as a whole (NT and Queensland Gulf of Carpentaria waters). In comparing estimates, we caution that the results were calculated 20 years apart using different methodology and different fishing areas.

Additionally, both the Northern Fisheries Research Committee (NFRC) and FRDC reports note that the biomass and yield numbers are subject to uncertainty and may easily be in error by factors of two or more.

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Table 3. Comparison of biomass, harvest fraction and yield estimates for all Gulf of Carpentaria waters as calculated by the Northern Fisheries Research Committee (NFRC) in 1991 and by the FRDC 2009/037 stock model in 2011.

Source	Biomass (t)	Harvest fraction	Yield estimate (t)
NFRC survey	17200	Not applied	Not calculated
NFRC production model	11820	8%	894
NFRC $F_{0.1}$ (Saddletail only)	14500	26%	3770
FRDC stock model	10860	6%	652

The main points to note from the 1991 GOC results and report by Sainsbury, Campbell *et al.* (1991) are:

- The fishery independent trawl survey conducted by CSIRO in the Gulf of Carpentaria assumed a 100% fish retention rate and a 45 m effective trawl path. The trawl gear had 9 cm mesh size and a 50% fish length selectivity of 25 cm; we assume this length measure was 'standard length'.
- Far NW survey locations were included as part of the 1990 survey (Figure 1 and Figure 2). Two survey sites in this area (1 and 28) recorded high catch rates of tropical snappers, 70-84% of which were identified as Saddletail Snapper. These sites belonged to the Arafura Sea fishery in FRDC project 2009/037 (Figure 3c).
- The total Gulf of Carpentaria trawl survey area was calculated to be 336 720 km^2. A smaller fishery area of 154 963 km^2 was considered in calculations for the Gulf of Carpentaria management zone; this area is not equivalent to Region 2 Qld GoC offshore in Figure 3e. Biomass calculations assumed tropical snappers (mostly Saddletail) occurred across the total trawl survey area. It is uncertain whether these area multipliers may result in over estimates, as detailed snapper habitat mapping was not available at that time.
- The 1990 trawl estimate of biomass was 17 200 t (range 10 300–38 700 t) for the whole survey area of the Gulf of Carpentaria (Figure 1). No TACC was calculated from this result. If a 6% harvest fraction was applied, the estimated TACC would equate to 1032 t (including some small non-commercial sized fish and the far NW survey locations).

- Estimates of MSY from the production model were described as difficult to calculate due to the limited catch, effort and age-frequency data before 1991. The MSY recommended for the Gulf of Carpentaria management zone (46% of the total survey area) was 894 t, equating to an 8% harvest fraction. The reported uncertainty range was 535–1788 t (page 20, Sainsbury, Campbell *et al.* 1991).
- The $F_{0.1}$ analyses used a Saddletail Snapper survey biomass estimate of 14 500 t (84% of 17 200 t of all tropical Snapper) and a $F_{0.1}$ harvest fraction of 26% (harvest fraction from page 14-15, Sainsbury 1990). The $F_{0.1}$ harvest fraction was heavily influenced by the assumed natural mortality rate of 33% per year for Saddletail Snapper. This value was much greater than current estimates (O'Neill, Leigh *et al.* 2011) and implied fish longevity of only about 10-15 years compared to sectioned otolith aging indicating longevity of up to 45 years (O'Neill, Leigh *et al.* 2011). The estimated $F_{0.1}$ yields were 3770 t (page 18 for Saddletail) and 4488 t (page 20 for tropical snapper) (Sainsbury, Campbell *et al.* 1991). In the calculations by Sainsbury, Campbell *et al.* (1991) the estimated survey biomass was not adjusted down as required to correctly specify $B_{F0.1}$, B_{MSY} or B_{40}. The yield-per-recruit estimates were instead scaled to the 1990 survey estimated biomasses (B_{1990}), which now have been quantified to be much greater than $B_{F0.1}$, B_{MSY} or B_{40}.
- In 1991, the GOC estimates from both the production model (894 t) and the $F_{0.1}$ analysis (4488 t) were considered to be lower and upper bounds, where maximum sustainable yield was believed to lie somewhere in between the two estimated values (Sainsbury 1990). To recognise the uncertainty, an initial TACC of 500 t was recommended for the northern Gulf of Carpentaria management zone (north of 12 S between 137–139 E and north of 13 S between 139–141 E). This TAC was added to the TAC for the Arafura Sea area (Sainsbury, Campbell *et al.* 1991).

From the FRDC stock model, the estimate of exploitable biomass was 10 860 t (commercial sized fish for the whole Gulf of Carpentaria; Table 2, Figure 3d&e), whereas the 1990 CSIRO estimates were 17 200 t of trawled biomass (all tropical snappers) and 14 500 t (*L. malabaricus*) for the GOC and south-east corner of the Arafura fishing zone (Figure 3c).

The FRDC stock model estimate of MSY was about 650 t for both east and west Gulf of Carpentaria waters (regions d and e, Figure 3). The MSY represented only the exploited commercial sized fish. The estimate was not too different from the NFRC production model. If the 1990 CSIRO biomass was adjusted to the FRDC report areas (regions d and e, Figure 3) and selectivity, and the 6% harvest fraction applied, then the estimate of MSY would be similar to the FRDC calculation. However, this adjustment was not done in 1991, possibly due to a different understanding of the fish biology (they assumed that tropical snappers were shorter lived), limitation of time series data, different management objectives and reference points for early development of the fishery, and the less advanced state of fishery stock assessment science at that time.

Are the MSY and stock status determinations consistent?

Commercial fishers have suggested that the reduction in the GOCDFFTF TACC is inconsistent with recent increases in fishing effort in the Northern Territory and the ‘sustainable’ stock status determination for northern Australian red snapper stocks of Saddletail Snapper (*Lutjanus malabaricus*) and Crimson Snapper (*L. erythropterus*) (Martin, Keag *et al.* 2014).

The MSY estimated by the FRDC stock model for the Queensland Gulf of Carpentaria cannot be compared with the results of the NT Saddletail Snapper SRA assessment because the SRA did not assess the Queensland region of the Gulf of Carpentaria. However, a comparison can be made between the results from the FRDC stock model for the Northern Territory regions (b, c and d in Figure 3) with the Saddletail Snapper SRA assessment in NT waters.

It is important to note the distinction between stock status determinations and the estimated MSY. Stock status indicates the current state of the stock (overfished/not overfished) at the time of assessment and the MSY indicates the maximum sustainable yield that can be taken over the long term. Both the FRDC stock model and the NT SRA assessment indicated that the red snapper stocks across northern Australia were not overfished.

The following compares MSY estimates for Northern Territory fisheries from both the FRDC stock model and the NT SRA assessment of red snappers.

FRDC stock model

The FRDC stock model estimated the exploitable virgin biomass for red snappers (Saddletail Snapper and Crimson Snapper) in the Timor Reef, Arafura Sea and the NT Gulf of Carpentaria to be about 40 100 t (Table 2). A 6% harvest fraction of this biomass equates to an approximate MSY of 2406 t for the whole of the NT fishery. For the Timor Reef and Arafura Sea regions, the virgin biomass estimate was 36 840 t and a MSY of 2210 t using a 6% harvest fraction.

NT SRA assessments

This section summarises the history of stock assessments and yield determinations for the Northern Territory (NT) red snappers Lutjanus malabaricus (saddletail) and L. erythropterus (crimson). The NT red snappers are managed separately to those from Queensland eastern GoC waters which exhibit different levels of population productivity (O'Neill et al., 2011). This summary aims to show that the most recent stock status results and calculated MSYs were consistent between the SRA and FRDC analyses. The analyses indicated that current biomasses are above those corresponding to maximum sustainable yield (i.e. stock status is ’not overfished’).

In 1991 the Northern Fisheries Research Committee (NFRC) calculated the original yield estimates for red snappers in the Arafura Sea. These estimates were derived from the same analysis methods used for the original yield estimates for the Queensland Gulf of Carpentaria and included the fishery independent trawl survey biomass estimates from across the Arafura and Timor Seas (Sainsbury, Campbell et al. 1991). The resulting yields for the Arafura Sea using the production model (837 t) and the $F_{0.1}$ analysis (4166 t) were considered extreme values, with the estimated sustainable yield somewhere in between the two values.

Ramm (1997) conducted the first Stock Reduction Analysis (SRA) for red snappers in the Arafura Sea. This assessment refined the yield estimates for red snappers in the Arafura Sea to around 1500–2500 t, based on an estimated biomass (in 1990) of 24 000 t.

Martin (2013) published a SRA on saddletail snapper, using data up to 2012 for all three regions of the NT (Timor Reef, Arafura Sea and the NT Gulf of Carpentaria). The year 2012 was the first period of increased effort in the Demersal Fishery following a change in management arrangements. Most of the information used for this SRA came from previous years when fishing effort was lower and saddletail snapper catches were less than 900 t. In 2012 the saddletail snapper catch increased to around 1500 t. This SRA indicated that the estimated MSY for saddletail snapper was in the range

1500–2000 t. The extrapolated SRA estimate of MSY for the combined red snappers (assuming 80% saddletail and 20% crimson) was 1800–2400 t (page 6, Martin, 2013).

In 2015 the Northern Territory government completed a more recent, as yet unpublished, SRA of saddletail snapper. This SRA included recent higher catches of above 2000 t as reported in 2014. This assessment estimated saddletail snapper MSY at approximately 1900 t (Dr T Saunders pers. comm. 28/4/2016). Extrapolation of this point estimate by 20% resulted in an approximate combined NT red snapper MSY of 2375 t.

The red snapper MSY estimated by both the SRA (Martin (2013) 1800-2400 t; unpub. (2015) 2375 t) and FRDC (O'Neill et. al. (2011) 2406t) assessments were consistent. Agreement between the results of the two different stock assessment models provides some additional degree of confidence in the MSY, although we note that both are largely dependent on the same fishery dependent information. It is especially notable that these two stock assessment models are also in agreement with biomass estimates from fishery independent trawl surveys in 1990, assuming that these surveys represented a biomass close to unfished (virgin) levels.

It is important to note that the forecasting ability of the SRA and FRDC analyses are subject to uncertainty and dependent on recruitment variation and historical levels of harvest. Given the available data, uncertainty (higher and lower possibilities) in the model estimated MSY is a reality for managers to consider in their risk management processes. In the short term, the MSY estimates can be taken as a reasonable basis to benchmark sustainable harvests. Harvest values less than MSY can be considered valid for management objectives aimed at high catch rates and fisher profitability.

The old TACC in Queensland waters (1250 t) and the current TACC in Northern Territory waters (3800 t) have been substantially under-filled for many years (18% to 34% filled in 2009). No fishing occurred in Queensland in 2014, but NT harvests have increased towards the TACC in the Demersal Fishery (2500 t) since 2012. The management strategy evaluations run by the FRDC stock model (O'Neill, Leigh et al. 2011) indicate that if fishing effort were increased at a moderate rate to consistently fill the old TACCs, major reductions in the long term harvests and catch rates would result. Further, short term observation of the possible impacts of higher harvests on fishery performance and data may not be obvious and may take some time to observe given inertia in the long life span of tropical snappers and the spatial patterns of fishing.

The following quote comes from a Northern Territory stock assessment workshop led by Dr Carl Walters of the University of British Columbia, one of the world's top fisheries scientists (p. 26, Ramm 1997b): 'Estimates of optimum annual exploitation rates range from 10–30%, but are low for most coastal species examined and for red snapper. Due to slow growth and low natural mortality rates, the stocks are expected to have accumulated large natural biomasses. But only low yields can be taken safely each year from such accumulations, so the high abundance seen in many areas should not be taken as evidence of high sustainable yields.' Further on, there are two separate estimates of a sustainable annual harvest. Firstly, the report equated the Ramm biomass estimate of 24 000 t in the fished population to a B_0 figure of 50 000 t for the Arafura and Timor Reef regions combined, and estimated the MSY to be only 1500 t (i.e. only 3% of B_0, in contrast to the figure of about 6% that we discussed above). In contrast, the final estimated range of sustainable yield in the Arafura Sea was reported as 1500-2500 t. This emphasises the level of uncertainty surrounding the currently available data.

What data are required for MSY estimation?

The FRDC 2009/037 project described data, methods, analyses and empirical management measures for tropical snappers. The report also highlighted how to apply quantitative methods in setting sustainable harvest and fishing effort. The simulation results demonstrated the technical advantage of using monitoring data within empirical management rules. In the simulations, the adaptive capacity of the data and harvest rules significantly improved management performance over setting a constant 'old TACC'.

The recommendations and conclusions from the FRDC project were (O'Neill, Leigh *et al.* 2011):

Catch rate data: Catch rates have large variance. To minimise variance, data must be recorded at fine scale (with location and effort for each trawl). Review and check on logbook reporting is required and made consistent across jurisdictions.

Age data: Aging protocols need to be standardised between agencies to minimise errors and bias. Ring-count data should be standardised to age groups (cohorts). Cohort-based analysis of age frequencies could be employed to estimate fishing mortality for management.

Monitoring program: Structured fishing locations are required every four years. It is critical for each sector's design to have randomly selected sampling units (trawling, trap or line) with spatial and temporal replication. If too few replicates are sampled, it can be difficult to separate confounding sources. The objectives for monitoring are to estimate the change in population abundances and age structures, so it is best to use the same general areas for quadrennial sampling. Spatial coverage of the stocks (including both heavily and lightly fished areas) is required, and must have an unbiased pattern. Accurate observer monitoring of tropical snapper catch rates requires a minimum number of 50 fishing days to be sampled per sector. Not more than 50 fish of one species in a single shot should be aged. Aging of more than 50 fish will not increase the precision of estimation of age structures. The selection of fish for aging should be random.

Total allowable catch or effort: can be adjusted every four years, after each monitoring episode, in order to maintain sustainability of the fisheries. More frequent setting is not necessary, although if catch rates fall to 70% or less of the reference value after two years, TAC or TAE can be reduced by 30% to avoid the need for more severe changes later.

FRDC modelling tool: The modelling tool should be used and maintained frequently for testing monitoring, assessment and management procedures. The model is operated by a user-friendly graphical user interface. The Bayesian hierarchical nature of the model provided a more accurate view of the status of the stocks as a whole than analysing each species and jurisdiction separately.

Improved cross-jurisdictional collaborations: Cross-jurisdictional monitoring, collation of data and management is a priority. The databases from the FRDC project should be used to store new data in future assessments. If management agencies do not adopt new monitoring and harvest strategies, precautionary levels of quota and effort are needed. TAC by species can be critically evaluated using the FRDC quantitative modelling tool.

In summary, monitoring every four years appears to offer reasonable prospects of managing the GOCDFFTF effectively. A minimum of 50 days of monitoring per four-year period is needed. A higher number of monitoring days would produce less year-to-year variation in the TACC and harvests.

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Appendix 1: NFRC Trawl Fisheries Assessment Working Group 29 July – 2 August 1991

Northern Fisheries Research Comittee
Trawl Fisheries Assessment Working Group
29 July - 2 August 1991

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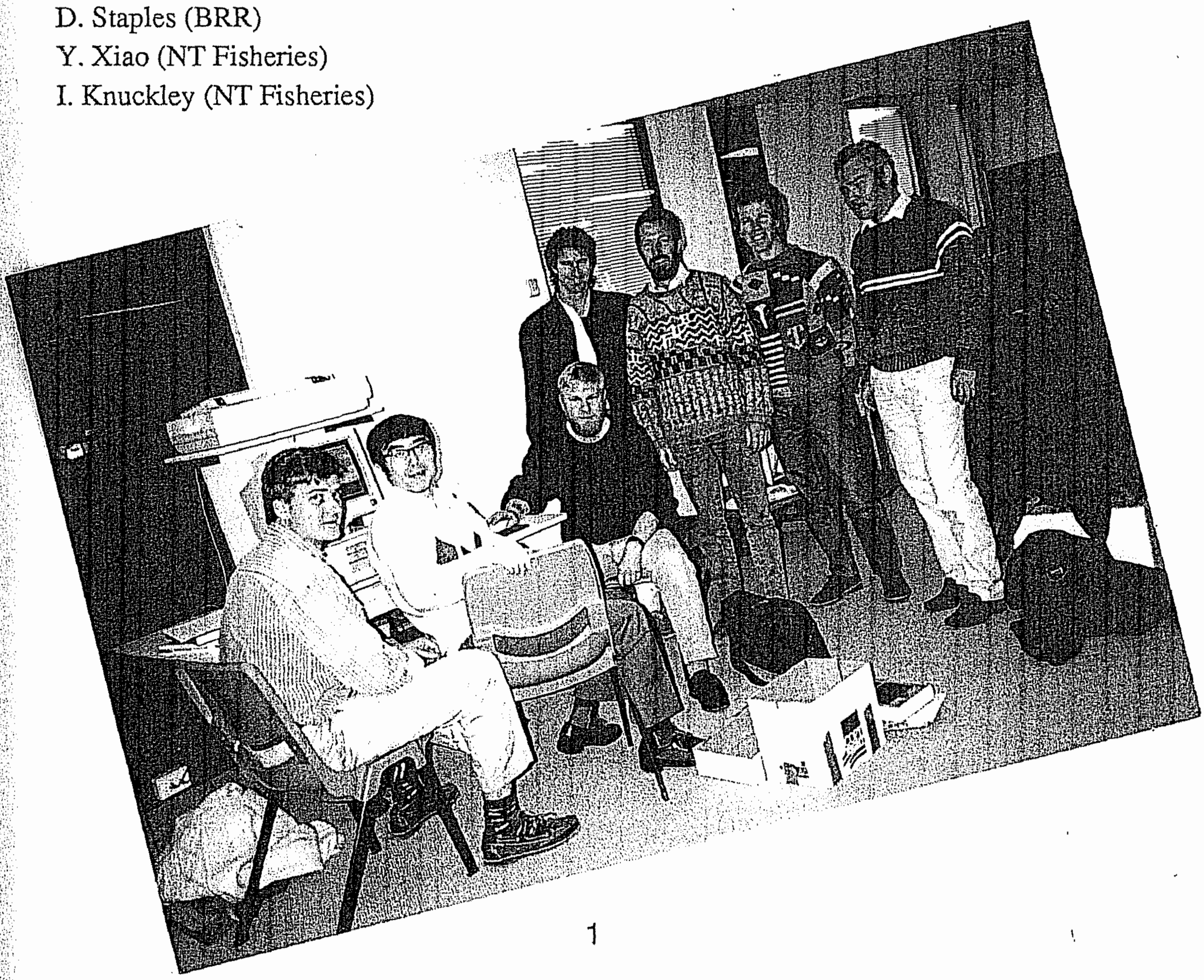
Participants

K.Sainsbury (CSIRO) - Chairman 29 - 31 July
R. Campbell (CSIRO) - Chairman 1-2 August
D. Brewer (CSIRO)
A. Harris (CSIRO)
K. McLoughlin (BRR)
D. Ramm (NT Fisheries)
D. Staples (BRR)
Y. Xiao (NT Fisheries)
I. Knuckley (NT Fisheries)



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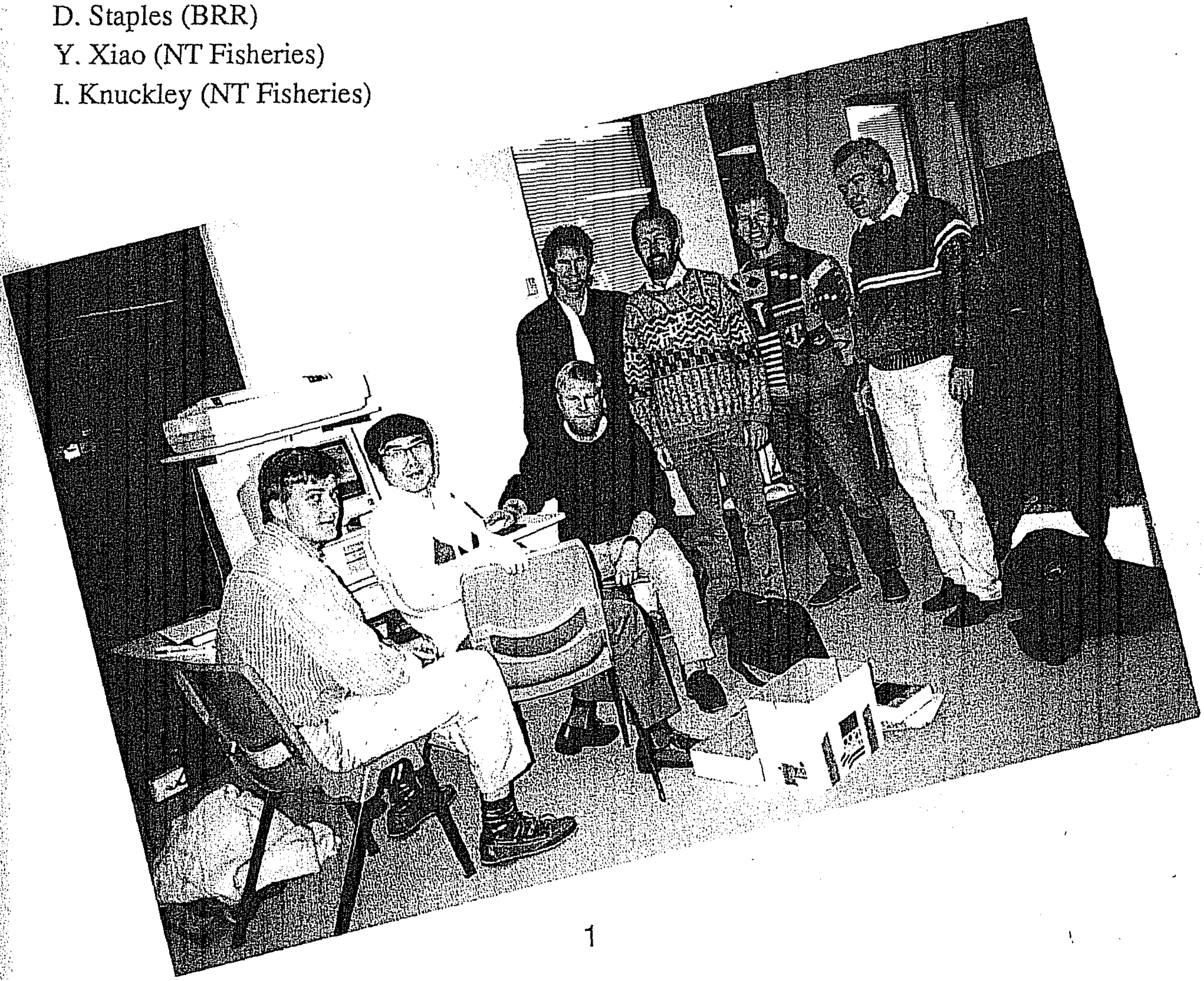

Report Structure

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1. Introduction

The objective of the Working Group meeting is to assess and provide yield estimates of the status of the northern demersal trawl fish resources managed under Commonwealth jurisdiction. The areas involved are the Timor Sea (excluding the 'Timor box' trap and line zone), Arafura Sea and central Gulf of Carpentaria that are within the AFZ (see Fig 1.1). It is anticipated that the North West Shelf resources (west of 123° 45') will come under the jurisdiction of Western Australia in the immediate future, and the Working Group was asked not to assess this region. However, some analysis is included for completeness.

The Arafura Sea resource between of 131-137°E was assessed at the 1990 Working Group meeting. The management objective given for the Arafura Sea was to maximise the sustainable yield of *Lutjanus malabaricus*, and the management tactic used was a catch quota applied to the total retained catch of defined 'prime fish' (see 1990 Working Group report for details). Two methods of yield calculation were used; a logistic surplus production model fitted to commercial catch and effort data, and a proportion appropriate for an $F_{0.1}$ harvesting policy times a biomass estimate derived from the commercial catch data. The surplus production model estimated that in 1989 the biomass of large *Lutjanus* commercial category (SN3) was about 14 000t, and that a sustainable yield of 1234t was available. Since *L. malabaricus* comprised about 0.7 of the large *Lutjanus* catch in 1989 this translated to a biomass and yield for *L. malabaricus* of 9800t and 866t respectively. Using the 1989 Thai catch data the biomass of *L. malabaricus* at the start of 1990 was estimated to be 13 885t, and an $F_{0.1}$ calculation gave a yield estimate of 3610t. Considerable difficulty was experienced in fitting the surplus production model because of apparent changes in catchability during the 1980s, but a conservative yield estimate was required by management and so a range of yield estimates based on the lower quarter of the 95% confidence region of the MSY estimated from the surplus production model were recommended. This gave a recommended yield of large *Lutjanus* of 600 - 900t and retained species yield of 1100-1650t. In 1990 a total allowable catch (TAC) of 1500t was adopted by management for the area of the Arafura Sea assessed by the working group, and an additional 500t was permitted to account for the addition of the northern Gulf of Carpentaria to the fishable area in 1990 (ie. a TAC of 2000t).

Because there was considerable difficulty interpreting the commercial catch and effort data, with consequent difficulty in estimating the present biomass and productivity of the resource, it was recommended that a demersal trawl survey be conducted to provide an independent estimate of the biomass of *L. malabaricus* in the Arafura Sea. This was conducted by the Northern Territory Fisheries Division. A demersal resource survey was also conducted by CSIRO in the Gulf of Carpentaria, in part to provide information on the resource available if that region was opened to demersal fish trawling.

2. Management background for 1991 assessment

The AFS manager of the northern trawl fishery, Dr R. Branford, provided an overview of the present management issues and developments. The main points made were:

Fishing fleets

No foreign trawlers are operating in the AFZ, and none were expected in future. Only domestic trawlers are active in the region. At present 6 vessels are endorsed to operate in the Arafura Sea zone (Fig. 1.1), and each is expected to land about 300t of *L. malabaricus* per year. No vessels have applied for endorsement to fish the Timor Sea. It should be noted, however, that the former Sea North Thai fleet is operating just north of the AFZ together with Taiwanese boats.

Management objectives and development plans

The management objective for the northern trawl region as a whole is to maximise the sustainable yield of *L. malabaricus*, and this is to be achieved by restricting the TAC. Other objectives are to preserve sea-bed structures of importance in maintaining populations of target species, and to promote development of a sustainable and profitable domestic fishery. The management measures considered for achieving these objectives include requiring that 'environmentally friendly' trawl designs be used, that the TAC be set low so as to allow development of high densities and hence catch rates, and to close some areas to fish trawling. The closed areas were seen as (i) encouraging development of non-trawl capture methods that yield high quality and value product, (ii) maintaining a 'sanctuary' for sea-bed structure and fish population, (iii) providing an area that will operate as a baseline for the measurement of the effects of fishing in the trawled areas, and (iv) providing an area which enhances the future options available to management.

Access areas

The Access areas used in 1991 are shown in Fig. 1.1. Dr Branford provided Fig 1.2 as the proposed access areas for 1992. The main features of the proposed new access areas are:

- The fish trawl access area is extended further into the Gulf of Carpentaria.
- A small area in the north eastern part of the Gulf is closed to provide a buffer for the Torres Strait.

- The previous Arafura Sea access area is divided into two (the Arafura Sea Zone and Gulf of Carpentaria Zone), so as to reduce the opportunity for taking from a small area the catch calculated as being appropriate for a large area.

- A buffer zone of no trawling between the new Arafura Sea and Gulf of Carpentaria Zones, so as to make enforcement easier and obtain the benefits of closed areas listed above.

- The south west corner of the 'Timor box' is modified in shape to match present perceptions of the boundary between the jurisdictions of Northern Territory and Western Australia.

The Working Group was requested to comment on the proposed structure of access areas and the incorporation of a buffer zone between the new Arafura Sea and Gulf of Carpentaria zones. The Working Group was requested to provide estimates of the yield available for each access area, based on the management objectives above and use of a TAC. Furthermore, an indication of the uncertainity in these estimates was to be provided taking into account the uncertainity in the data and the assessment methods used. It was agreed that it was the managers reponsibility to set TACs based upon this information.

Trawl designs and mesh size

During 1990 a the 'Julie-Anne' trawl design was developed by the Northern Territory Department of Fisheries (Mounsey and Ramm, 1991). Trials indicated that this trawl causes less damage to the epibenthic structure of the seabed than the trawl design usually used by the fishing fleet, that it does not catch less of the target fish species, and that the condition of the fish caught is superior. The Working Group was requested to comment on the desirability of requiring that the 'Julie-Anne' trawl design be used in the fishery. The present minimum mesh size is 90mm, but apparently most (and perhaps all) vessels are using mesh sizes of 100-120mm. The orking group was asked to recommend an appropriate mesh size.

3. Data available and used in assessment

The data available for all of the northern trawl fishery areas (ie. from the North West Shelf through to the Gulf of Carpentaria) are summarized here for completeness, although the data from west of 123° 45' are not needed here for fisheries assessment purposes.

a) Taiwanese logbook data (1972-1979)

These data are derived from the annual reports of the Taiwanese catch and effort data

(Anon. 1972-79) and a computer tape of the same data provided by the Taiwanese, as described in last year's Working Group report.

b) AFZ logbook data

Shot specific catch, converted to number of boxes, and effort data for the Taiwanese fleet during 1980-87 were the same as those used at the 1990 stock assessment workshop. Shot specific catch and effort data for the Taiwanese fleet 1988-90, Thai fleet 1985-90, Chinese fleet 1989 and domestic fleet 1988-91 were those processed by the Northern Territory Fisheries Division on behalf of AFS. All foreign logbook data were verified during early 1991. Verification routines included: ranges, trawl duration ; trawl sequences; and, distance trawled (Ramm, in prep). Domestic data have been checked by double-punching. No verification routines have been run on these data, and the 1991 data are incomplete.

Total catches and CPUEs by commercial category were extracted by fleet, management zone and year 1980-91. Each record in the logbook data was assumed to represent a single trawl. However, CPUE analysis rejected records with: missing values for month and trawl duration; positions beyond 5-25^{o}S and 100-150^{o}E; and, trawl durations > 8h. Records with total retained catch=0 were treated as "blowouts", rather than missing values, and were accepted for CPUE analysis. The proportion of records accepted was used to scale total catches and effort to 100% of records available. Details on the data files are summarised in Table 3b1.

Much of the Chinese and domestic logbook data consisted of shot specific effort data, and day specific catch data. These data were used to calculate the catch and effort for an average trawl for each particular day; this average was used for CPUE analysis. Such treatment of the data resulted in a low proportion of data accepted (Table 3b1).

c) AFZ Observer Data

Data collected by observers aboard Taiwanese and Thai trawlers were used to determine the mean weight of fish boxes, and the proportion of *Lutjanus malabaricus* within the commercial category "large lutjanids" (SN3). Box weights pooled over commercial categories, management zone and years 1985-90 were used to determine the mean box weight (w) for:

-Taiwanese fleet w=31.8kg 95%ci=0.5kg n=844; and,
-Thai fleet w=24.0 95%ci=0.1kg n=3001.

The mean box weight for the Chinese fleet was taken as 10kg (AFZ Observer reports). The mean box weight for the domestic fleet was taken as 24kg during 1987-88, and 10kg during 1990-91.

In the absence of data on processing activities, all catch data reported in the logbooks are assumed to be for whole fish.

The proportion of *L. malabaricus* within the SN3 category was that used in the 1990 stock assessment workshop (ie 70% by weight).

d) Research Vessel Survey Data

i) Timor and Arafura Seas

During October-December 1990, the Northern Territory Fisheries Division conducted a trawl survey between 127-137^{o}E and depths ranging from 20-200m. Total shiptime was 53 days. The sampling strategy was based on that used by CSIRO during annual surveys on the North West Shelf. Samples were collected during daylight using a 28m Frank and Bryce trawl with 44mm mesh in the cod-end. The trawl duration was 30 minutes. Data collected included: weight of each species of fish caught; length of fish from selected species (including all *Lutjanus*); salinity and temperature profiles; and, video-photography of the habitats traversed by the trawl. Fish of selected species were also retained for further investigation in the laboratory.

25.6m headline 84 ft.

The survey covered an area of 306,600 km^2, and included total and partial surveys of the 4 management zones:

- -Arafura Sea foreign access zone (118600km^2);
- -Timor Sea foreign access zone east of 127^{o}E (34900km^2);
- -Timor Box (68100km^2); and,
- -NPF seasonal closure zone between 127-137^{o}E (85000km^2).

Stations were allocated to each zone in proportion to the area of the zone and the position and direction of each trawl was random. In all, 207 stations were successfully sampled; a further 6 samples were lost due to net damage. The distribution of catches of *L. malabaricus* is shown in Figure 3d(i)1 and estimates of the biomass of *L. malabaricus*, all large *Lutjanus* and all species in the survey area are given in Tables 3d1 (a-c) for a range of trawl retention and effective trawl widths.

ii) Gulf of Carpentaria

Between 21 November and 12 December 1990, the CSIRO Division of Fisheries carried out a survey of the Gulf of Carpentaria and the AFZ to the north. The objectives were to determine the distribution of demersal fish fauna and benthos of the Gulf of Carpentaria. The surveyed extended from 136.5 E to 141.5 E in depths of 20 to 85 m (Figure 3dii1). There have been few previous fish surveys of the Gulf and none with the same extent. The survey had a systematic design with a sampling unit of 30 by 30 nm . At 106 stations, a 28m Frank and Bryce trawl was fished for 30 mins at a speed of ca 3.3 knots. All fish taxa were identified, counted and weighed. Commercial fish and those fish species that were known to eat prawns were measured and otoliths, gonads, and guts taken. At each station the macrobenthos from a Church dredge, infauna and sediment from grabs, were collected and temperature / salinity / depth profiles taken. The distribution of catch weights of *L. malabaricus* is shown in Figure 3d(ii)2. Estimates of the biomass of *L.malabaricus*, all large *Lutjanus* and all species (day and night) in the survey area are given in Tables 3d2 (a-d) for a range of trawl retention and effective trawl widths.

4. Assessment of the Arafura Sea

4a General description of the catch and effort data.

Taiwanese catch and effort data for (1971-90), Thai data for (1985-90) and domestic trawl data for (1987-90) were available (Table 4a1). The 1980-89 Taiwanese estimates of catch given in Table 4a1 differ slightly from those listed in last years report because the weight per box was treated differently. All catch and effort data were combined with each fleet's effort standardised according to a relative fishing power for that fleet. This was taken to be the ratio of the annual cpue for that fleet with the Taiwanese fleet (Table 4a2). Due to the very small Taiwanese effort in 1989 (22 hours), the fishing power for the other fleets was taken to be the average of the 1988 and 1990 results.

Catch per standardised effort is plotted against year for the total retained catch and for large *Lutjanus* in Figures 4a1. As was pointed out in last year's report the large *Lutjanus* cpue shows a jump in 1980 and steady increase since then, with catch rates since the mid-1980s exceeding those of the first years of the fishery. This change was assumed to be caused a shift in targeting onto large *Lutjanus* in the 1980s. The catchability in year T was therefore modelled as follows;

$$q(T) = q \quad T<1980$$

$$q(T) = q\,(1+ s + a\,(T - 1979)) \quad T >= 1980$$

Note that this is slightly different than the model used last year as it was found last year that the increase in the catchabilty showed no indication of an asymptote.

4b Production model analysis.

The results of the production analysis for large *Lutjanus* are given in Table 4b1. The model provides a reasonably good description of the catch history. The parameter estimates indicate a jump of 50% in the value of q in 1980 and a substantial increase during the 1980s from .115E-6 in 1979 to .70E-6 in 1991. The estimated maximum sustained yield for large *Lutjanus* is 927 tonnes, and at equilibrium this would be obtained with an effort of 8185 hours at the 1991 catchability. The approximate 95% confidence interval for the MSY is from 65 to 5185 tonnes, though the distribution is highly skewed. An 'effective' upper 95% limit can be taken to be 2624 tonnes. The biomass of large *Lutjanus* at the start of 1991 is 12,252t (approx. 95% confidence interval 500-25,000) , or 38% of the virgin biomass of 32,400t.

4c Biomass estimates.

Together with the results of the surplus production model, estimates of the fish stock biomass for the Arafura Sea and Gulf of Capentaria access areas are given from two other sources;

i) research cruise estimates,

ii) fishing fleet data using an area swept method.

(i) Research data

Biomass estimates from the NT research cruise data for *L. malabaricus* and all large *Lutjanus* in the Arafura Sea management zone (131-137E) are given in Tables 4C1(a-b). Note that estimates are given for a range of retention and effective trawl path parameters. *L. malabaricus* was found to account for 78% of the total large *Lutjanus* catch. Similarly, biomass estimates from the CSIRO research cruise data for *L. malabaricus* and all large *Lutjanus* in the Gulf of Carpentaria management zone (137-141 20'E) are given in Tables 4C2(a-b). *L. malabaricus* accounted for 84% of the total large *Lutjanus* catch.

There is no quantitative estimates of retention or herding available for *L. malabaricus.* Experiments were conducted on the North West Shelf in 1982 to estimate these parameters for a number of species, but unfortunately the catch rate of *L. malabaricus* was too low to permit estimation for this particular species (the same was true for all large *Lutjanus* species). Our 'best guess' for *L. malabaricus*, and these could only be qualitative at best, is based on the trawl retention of *Lethrinus choerorynchus* (a fish with a similar body shape) and the avoidance of *Lutjanus vittus* (a small bodied species of the same genus).

For Frank and Bryce trawl as a whole (ie. not just cod-end) the proportion of *Lethrinus choeroynthus* retained by the net was 0.96 (std error approx. 0.05); consequently a very high retention proportion is expected for *L. malabaricus*. The catches of *L. vittus* indicate that herding results in an extension of the effective trawl pathwidth beyond the width of the trawl net, and that this extension is about one quarter of the extra path width provided by the trawl doors. For a typical Frank and Bryce tow, with a wing-tip separation of 20m and a trawl door separation of 75 m, the effective pathwidth is about 20+.25*(75-20)=33.7m. It is not known how this relates to *L. malabaricus*, but it seems reasonable to assume that *L. malabaricus* is more mobile and responsive at greater distances than *L.vittus* and so to expect herding to be more effective in *L.malabaricus*. Overall, then, it appears reasonable to expect for *L.malabaricus* a high retention proportion (say greater than 0.90) and a moderate extension of the pathwith beyond that of the trawl net (giving a reasonable range of an effective pathwidth of say 30-60m for the Frank and Bryce).

Using a retention of 1.0 and an effective pathwidth of 45m the estimated biomass of large *Lutjanus* in the Arafura Sea MZ and the Gulf of Carpentaria MZ are 16,100t and 17,200t respectively. Since the greatest error in these biomass estimates arises due to the error in the assumptions concerning pathwidth, a range for the biomass estimate can be obtained by taking upper and lower estimates given for a pathwidth of 20 m and 75 m respectively.

	Biomass	Range
Arafura Sea MZ	16,100	9,600 - 36,200
Gulf of Carpentaria MZ	17,200	10,300 - 38,700

The biomass at the start of 1991 from the production model analysis was given as 12,252 tonnes and has an effective 95% confidence range of 405 to 25,370 tonnes. Area, however, is not explicitly incorporated into the production model, and so there is no explicit means of determining the area to which the estimated yield or biomass applies. The estimates apply to an area that will be some complicated combination of the area fished by the fleet that generated the data being analysed and the exchange rate of animals between the fished area and adjacent unfished areas. In the present circumstance the area fished also changed considerably during the period being analysed, mainly as a result of constraints imposed on access areas (eg. there has been no foreign access east of 137E during the last few years). Production models are known to perform poorly in this spatially varying situation, and there is no way of taking account of these spatial considerations without substantial additional data (on movement rates in particular). The analysis can be done separately for smaller regions and the combined results compared with a single aggregate analysis of the larger region to get some idea of the sensitivity, but unfortunately this was not possible in the time available to the Working Group because of the time required to manipulate the data-base for such a comparison. Since knowledge of the spatial structure and movement patterns of large *Lutjanus* in the Arafura Sea is lacking, the approach taken here is to assume no exchange of fish between the fishing grounds and surrounding areas and that the effective area to which the production model applies is the area providing most of the catch during the period spanned by the analysis.

Investigation of the spatial extent of the total fishing grounds of large *Lutjanus* for the years 1971 to 1990 (Figure 4c1) showed that the majority of the catch within the AFZ access zones had taken place between 133E and 137E in the Arafura Sea MZ and north of 12S between 137E and 139E and north of 13S between 139E and 141E in the Gulf of Carpentaria MZ (areas 2 and 3 on Figure 4c2). To account for shifts in the spatial distribution of catches (mainly due to shifts in access boundaries), the spatial extent of the catches of large *Lutjanus* for each year (see 1990 Working Group report) were examinated and indicated that, on average, an area equivalent to about 77% of area 2 and 58% of area 3 was fished throughout the entire period. The 'production model effective area' (PMEA) for which the production model biomass can be related was therefore taken to be 129,000 km^2.

To calculate the estimated biomass of large *Lutjanus* in the PMEA using the research cruise data, average densities of large *Lutjanus* within the four areas defined on Figure 4c2 were calculated (Tables 4d1(a-c) and 4d2(a-b)). The results for each area, taking the values of the retention and width parameters used before, are as follows;

Zone	Area	Density	Biomass	Biomass Range
1	31,000	0.071	2,200	1,320 - 4,960
2	88,000	0.145	12,730	7,640 - 28,660
3	105,000	0.131	13,760	8,260 - 31,000
4	50,000	0.066	3,300	1,980 - 7,410
PMEA	129,000	0.138	17,830	10,670 - 40,050

It is interesting to note that the densities in the two areas accounting for most of the large *Lutjanus* catch (2&3) is double the density in the other areas with little, if any, fishing. It appears that the fleet learnt early on where the best catches are to be obtained.

Relating the production model yield of 927t to the PMEA of 129,000 km^2, the estimated yield from each area can be calculated. Given a yield Y1 in area 1 with biomass B1, then the yield in area 2 with a biomass B2 is given by;

$$Y2=(Y1*B2) / (B1)$$

Using the biomass ranges for each area provided above, an estimate of the range of yields for each access area similarly be calculated. The results are as follows;

Zone	Prod Mod Biomass	Research Biomass	Estimated Yield	Yield Range
PMEA	12,252	17,830	927	554 - 2,082
Arafura MZ	11,060	16,100	837	500 - 1,882
Gulf MZ	11,820	17,200	894	535 - 1,788
	22,880	33,300	1,731	1,035 - 3,670

The estimated yield of large *Lutjanus* from the Arafura Sea MZ and the Gulf of Carpentaria MZ is therefore estimated to be 837t and 894t respectively.

(ii) Commercial data

In 1990, the Working Group estimated the biomass of large *Lutjanus* using the commercial data and and area-swept method. In the absence of distributional data, biomass in mid-1989 was estimated from the average cpue in each 6x6 minute (NPF grid system) fished by the Thai fleet between 131-137^{o}E. The width of the effective trawl path was taken as 25m with 100% trawl retention, and the area swept was taken as 0.16km^2/h. Data collected during the trawl surveys indicate that large *Lutjanus* are uniformly distributed throughout the grounds of the Arafura fishery. Under the assumptions made with the trawl survey data, the effective trawl path of the commercial gear may be 45m with 100% retention. This assumption increases the area swept to 0.29 km^2/h.

The average catch rate of large *Lutjanus* for the Thai fleet in the Arafura Sea management zone in 1989 was 69.7 kg/h (95% ci = 0.9 kg/h). The average density is 240 kg/km^2. The area of the fishing ground is approximately 129,000 km^2 giving a mid-year biomass estimate of 30,960t. The total retained catch of large *Lutjanus* was 4270t so the estimated biomass at the start of 1990 is 28,820t (cf 17,830t using research data). This estimate should be regarded as biased upwards given the strong likelihood of targetting of large *Lutjanus* by the commercial trawlers. As such this estimate will not be considered further.

4d $F_{0.1}$ analysis.

The $F_{0.1}$ yield was calculated for *Lutjanus malabaricus*. A description of the method and calculation of the F corresponding to an $F_{0.1}$ strategy are given in last year's report. For a mesh size of 9 cm an F of 0.26 was found.

The biomass of *L. malabaricus* in each management zone is given from the research survey data in Tables 4c1(a) and 4c2(a). Using a retention of 1.0 and pathwidth of 45m, as used above, the estimated biomass of *L. malabaricus* in the Arafura Sea MZ was 12,500t giving an $F_{0.1}$ yield of 3,250 tonnes. Similarly, for the Gulf of Carpentaria management zone the estimated biomass of *L. malabaricus* of 14,500 tonnes gives an $F_{0.1}$ yield of 3,770 tonnes. As before a range can be obtained for these estimates. The results are summarised in the following table.

	Biomass *L. malabaricus*	Yield of *L. malabaricus*
Arafura MZ	12,500 (7,500 - 28,100)	3,250 (1,956 - 7,306)
Gulf MZ	14,500 (8,700 -32,500)	3,770 (2,262 - 8,450)

From the reseach survey data the proportion of *L. malabaricus* in the total large *Lutjanus* catch was 78% in the Arafura Sea MZ and 84 % in the Gulf of Carpentaria MZ. If these proportions remain constant, then the sustainable yield of large *Lutjanus* in the Arafura Sea MZ can be taken to be 4,166t (2,508t - 9,367t) and for the Gulf of Carpentaria MZ 4,488t (2,693t - 10,060t).

5. Assessment of the Timor Sea

Taiwanese catch and effort data (1972-90), Thai data (1986 -1989), and Chinese data (1989) were available (Table 5a1). The annual cpue for each fleet is given in Table 5a2 fot large *Lutjanus* catches.

The surplus-production model is not appropriate for the analysis of these data due to the limited nature of the catch and effort information for this stock. Using the biomass estimate for *L. malabaricus* estimated from the research survey data, an $F_{0.1}$ yield estimate can be calculated. The density of *L. malabaricus* in the area surveyed on the Timor Sea is given in Table 5a3 and, using similar retention and pathwidth parameters as above, an estimate of 0.121t/km^2 (range 273 - 73) is found. The area surveyed was 34,900 km^2 giving an estimated biomass for this area of 4,233t and for an $F_{0.1}$ fishing strategy the estimated yield of *L.malabaricus* is 1,097t (660t - 2477t). *L.malabaricus* was found to comprise 98% of the large *Lutjanus* catch for this area, so the corresponding yield of large *Lutjanus* is 1,119t (674t -2,528t).

The total access area on the Timor Sea is about 122,000 km^2. However, no estimate of the biomass for the area outside the survey area is available, or is the distribution of the *L.malabaricus* in this area known. Assuming a uniform distribution across the entire management zone, the estimated yield of *L.malabaricus* is 3,847t. Using an estimate of the sustainable yield in the same proportion as the $F_{0.1}$ result for the Arafura Sea gives a yield for *L.malabaricus* in the Timor Sea MZ of 915t and 934t for all large *Lutjanus*.

6. Assessment of the North West Shelf

6a General description of the catch and effort data.

Taiwanese catch and effort data (1972-90), Chinese data (1989) and domestic trawl data (1989-90) were available (Table 6a1). All catch data were combined with effort standardised by comparing the annual cpue for each fleet (Table 6b2). Domestic trap and line data were also available but not by species, and so was not used in the following analysis.

The cpue for large *Lutjanus* by the Taiwanese shows a major increase in the last two years. As in the Arafura Sea, the Taiwanese fleet appears to be targeting large *Lutjanus* and this is supported by a considerable increase in the proportion of large *Lutjanus* in the retained catch (see 1990 Working Group Report). Large *Lutjanus* represent a higher proportion of the retained catch (39% in 1989 and 34% in 1990) for the domestic trawl fleet, though the cpue for this group is considerably lower than that for the Taiwanese during 1989 and 1990. It is obvious that the domestic fleet is trashing a higher proportion of the catch than the foreign fleets, with large *Lutjanus* representing a major target group. The detailed analysis of targeting and the spatial movement of the resource recommended in last years report has not been undertaken. This recommendation still stands. By ignoring the effects of these changes in the present analysis an over-optimistic assessment of the resource is expected.

6b Yield analysis.

The results of the logistic surplus production analysis of the large *Lutjanus* with a constant catchability are given in Table 6b1. The yield estimate for this resource is 600 t, (similar to last year's result of 612 t) and as this group comprised 34 % of the total catch for the domestic fleet in 1990, this corresponds to a total all species yield of 1764t. Past changes in mesh size and discarding by the Taiwanese are more complex on the North West Shelf than in the Arafura Sea and so, the production model approach, which cannot account for changes in mesh size, is not particularly appropriate.

Time limitations did not allow any further analysis using other methods. Carrying over last years recommended yield of 200 tonnes for *L.malabaricus* and 287 tonnes for large *Lutjanus*, and using the result that the large *Lutjanus* comprised 34% of the total domestic catch, an all species yield is 844 tonnes.

7. Zonation and buffer areas

7a Zones

The working group was requested to assess the desirability (or otherwise) of managing the Northern Demersal Trawl Fishery in three separate zones (Timor Sea, Arafura Sea and Gulf of Carpentaria (Fig 1.2)). The main objective of such a system is to distribute catches and fishing effort over a wide area to avoid concentrated effort on fish aggregations. Because there are few data on the stock structure of the fish and community structure of the areas or the degree of movement of fish between zones, managing by zones is a conservative approach i.e. managing one stock over three zones could be inefficient but will not damage stocks whereas managing two stocks by one zone could result in overfishing if the catch intended for both stocks were taken from one.

It is RECOMMENDED that zones be created with support for analysis of the community structure in the different areas (existing survey data) and research on the stock structure of *Lutjanus malabaricus*.

7b Buffers

The existing management plan includes a buffer zone. The Timor Box area has been designated as a non-trawl area for fish and provides a buffer zone between the Timor Sea and the Arafura Sea. Another buffer zone between the Arafura Sea and the Gulf of Carpentaria has been suggested (Fig 1.2). Total effort for the past 10 years has concentrated in two main areas (Figure 7b1); North-west Shelf and a band across the Arafura Sea and north of the Gulf of Carpentaria. The proposed buffer zone cuts through this second area of high fishing effort.

The main objectives of introducing a buffer are to:

- . Provide for more effective policing of fishing zones
- . Provide a baseline "unfished" zone for comparison with fished zones
- . Provide a refuge area
- . Provide an area for the exclusive use of non-trawling fishing methods

The effect of this closure will depend on the extent of movement of the different species of fish. If the species of interest (eg. *L. malabaricus*) is a mobile species, then a buffer zone will not result in any loss to the fishery as the fish will still be available to the fishery. As a corollary the buffer zone would not act as an effective refuge. In contrast, if the species is sedentary, then the available biomass will be reduced. Based on catch data for the past 10 years, this would amount to a 33% reduction in catch in the Arafura Sea stock (Table 7b1) and provide a refuge for this percentage of the stock.

In terms of the other objectives, the proposed buffer zone is not in a good position to provide an area of alternative fishing. Apart from 2 shoals (Duddell and Vosella) the habitat is unsuitable for trapping or long-lining and it unlikely to produce good yields of species such as L. *malabaricus*.

There is a good argument for having buffer zones in meeting the objective of providing a control "unfished" zone, providing the closure is enforced and left long enough to recover from past fishing. The buffer could be of value in examining habitat recovery and determining the extent to which observations on habitat destruction and recovery from the North West Shelf are applicable to areas such as the Arafura Sea. Anecdotal evidence and preliminary survey data suggests that the massive changes which occurred on the North-west Shelf have not occurred in the Arafura Sea and species such as *L. malabaricus* are not particularly sensitive to habitat destruction. This hypothesis requires further testing.

It is RECOMMENDED that a buffer zone be introduced off the Wessel Islands providing that resources are also provided to support a monitoring program which would provide research data relevant to the problem of "environmentally-friendly" nets, habitat recovery and degree of movement of different species. It is noted that the value of the buffer zone as a baseline for comparison with fished zones would only be realised if observations and surveys were conducted in the buffer zone.

8. Mesh size and trawl design

The effect of mesh size on the yield estimate was considered during last year's workshop.

A yield per recruit analysis indicated that the legal minimum of 9cm mesh was too small to maximise the yield of the total fishery. For L. *malabaricus*, the maximum yield per recruit occurs at a mesh size of 17cm. This mesh size also affords a greater protection of the spawning stock. It must be stressed again, however, that we have no data for mesh sizes above 10cm and that this result is an extrapolation. It is RECOMMENDED that mesh selectivity experiments be carried out and include the effect of square mesh.

Following the encouraging results of the net trials conducted by the Northern Territory Department of Primary Industry and Fisheries (Mounsey and Ramm 1991), the Working Group was requested to advice on the compulsory introduction of semi-demersal nets into the Northern Demersal Trawl Fishery. The NT Dept of Primary Industry and Fisheries found that a semi-demersal net (named "Julie Anne") was catching only 3% of the benthos and 43% of the bycatch (by weight) caught in a conventional bottom trawl. Catches of commercial species, including the "red" snappers (L. *malabaricus* and L. erythropterus) was similar between nets for 9 species. Catches of 3 species (including blacktip shark) was higher and catches of another 5 (including painted sweetlip) were lower. The semi-demersal trawl reduced the bottom contact of the trawl and rigging to 3% of the width of the trawl path and significantly reduced damage to the substrate. Additional benefits of the semi-demersal trawl included higher quality fish (less damage due to bycatch and benthos) and reduced wear on the net and rigging.

The Working Group accepted that more trials of this type of gear would be desirable,particularly to include other habitats and areas, but concluded that given the large apparent advantages in using an "environmentally-friendly" net in the area its use should be encouraged. The Working Group, therefore, RECOMMENDED that the use of semi-demersal net be made compulsory but to be phased into the fishery over a period of at least one year. The Group also RECOMMENDED that detailed catch data be collected during the phasing-in period to provide more data on the effectiveness of the semi-demersal net and also provide the comparison for future stock assessments.

9. Conclusions and Management Implications

In contrast to last year, this year's assessment of the status of stocks was based on both commercial fishery data and research survey data. Following two very successful research cruises by the NT Department of Primary Industry and Fisheries in the Arafura Sea and CSIRO in the Gulf of Carpentaria, independent data on the biomass of fish stocks were available. Comparisons of the densities of fish caught in the two surveys indicated that the two surveys were producing comparable results. However, to compare the estimates of biomass calculated from commercial data with the surveys, it was necessary to make an assumption on the efficiency of the trawl net used in the survey and also to select subsets of data so that the biomass referred to the same area ("historical fishing area"). The assumption (based on observations in other fisheries) was simply that the net retained a high proportion of large *Lutjanus* and also the bridles herded fish into the net. Based on this assumption, there was good agreement on the amount of fish present in the fishing area in 1990. For further assessments, an average "best estimate" of the biomass was used for further calculations.

Two models were used to calculate the sustainable yield of large *Lutjanus* and *L.malabaricus* for the four management zones.

Large *Lutjanus*	Arafura	Gulf	NW Shelf	Timor
$F_{0.1}$ estimate	4,166	4,488	-	1,119*
	(2,500-9,370)	(2,690-10,060)		(674-2528)
Surplus Prod.	837	894	600	-
	(500-2,080)	(535-1,788)	(436-810)	

* incomplete data

L.malabaricus	Arafura	Gulf	NW Shelf	Timor
$F_{0.1}$ estimate	3,250	3,770	-	1,097*
	(1,960-7,310)	(2,260-8,450)		(660-2,477)
Surplus Prod.	652	751	420#	-
	(390-1,620)	(485-1,481)	(305-567)	

* incomplete data.
# proportion of *L.malabaricus* in large *Lutjanus* catch assumed to be 70%.

As was the case in last year's assessment, values for the $F_{0.1}$ method were higher than those calculated by the surplus production model, although having the new biomass estimates has made the two estimates more similar. Despite the very good results coming from the surveys there is still considerable uncertainty in both estimates, although we have more confidence in the current biomass figures than before. The main concern in the production model estimate comes from the need to "explain" the increase in catch of large *Lutjanus* which occurred after 1980. This has been interpreted as being caused by increased targeting and has been modelled accordingly. This interpretation could lead to an under-estimation of the naturtal productivity of the large *Lutjanus* stock and a corresponding depressed yield estimate. The $F_{0.1}$ estimate, on the other hand, is based on life-history parameters from studies on *L. malabaricus* from other areas (the North West Shelf - see last year's report) and also includes the assumptions concerning the efficiency of the sampling gear. Futhermore, the catch and effort in this fishery has not been steady over the years and so the age structure is unlikely to be at equilibrium as assumed by this model. The effect of past high catches on the spawning stock is not known. To account for these uncertainties, we calculated upper and lower limits in the yield derived from both methods. These give extreme values and it is likely that the sustainable yield will lie somewhere between the two estimates. We accepted the $F_{0.1}$ estimate as the upper boundary and the surplus production model estimate as the lower boundary.

Setting TACs from these yield estimates will depend on the management objectives. This year's recorded catches in the Timor Sea and Arafura Sea (350 tonnes as of May 1991) are much lower than the allocated TACs. However, because these data do not include catches of Thailand and Taiwanese fishermen working in Indonesia waters (15 Thailand vessels are currently working just north of the AFZ), the exploitation rate will be much higher than indicated by Australian catches if the fish move across the boundary. The effect of these catches is difficult to determine and will depend on the structure and mobility of the stock, but the unknown extent of their influence would suggest that a cautious approach to TAC setting would be advisable. As the domestic fleet appears to be retaining only large *Lutjanus* (Ramm, pers. comm.) it is appropriate to set a TAC based on the estimated yield of this species group alone.

For future assessments it is imperative to have catch data from these foreign fleets and also to conduct scientific research to improve our knowledge of stock structure, movements and basic biology of the component species (see RECOMMENDATIONS).

The working group was also asked to assess the effectiveness of managing the fishery in 3 main zones (Timor Sea zone, Arafura Sea zone and Gulf of Carpentaria zone) with the introduction of a buffer zone north of the Wessel Islands (Fig. 1.2). The Group recommended the introduction of management zones and the buffer zone with the proviso that sufficient funding be made available to monitor the changes that occur in the buffer zone.

10 RECOMMENDATIONS

The working group RECOMMENDS that:

. As the domestic fleet appears to be retaining only large *Lutjanus* in the Arafura Sea and Gulf of Carpentaria management zones TACs in these zones should be based on the estimated yield of this species group alone.

. The sustainable yield estimates for large *Lutjanus* given in the table below be used to set TACs in the Northern Demersal Trawl Fishery (NDTF), bearing in mind the uncertainty in the estimates and the unknown impact of foreign vessels on Australian stocks.

Large *Lutjanus*	Arafura	Gulf	NW Shelf	Timor
F0.1 estimate	4,166 (2,500-9,370)	4,488 (2,690-10,060)	-	1,119* (674-2528)
Surplus Prod.	837 (500-2,080)	894 (535-1,788)	600 (436-810)	-

* incomplete data

. The NDTF be managed in several zones with buffer areas set up to provide scientific data on the effects of trawling in the fishery

. Environmentally friendly nets be made compulsory in the fishery with a phase-in period not less than 1 year.

. More research be conducted to reduce uncertainty in the yield estimates. Priority areas include:

- . Repeat surveys at a different time of the year to include a wider coverage, especially north of the AFZ.
- . Quantification on escapement and herding of the survey nets
- . Better estimates of growth and natural mortality of large Lutjanus species
- . Studies on stock structure and movement of fish.

References

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Mounsey, R.P. and Ramm, D.C. (1991) Evaluation of a new design of semi-demersal trawl. Fishery Report #25, N.T. Dept. Prim. Ind. And Fish.

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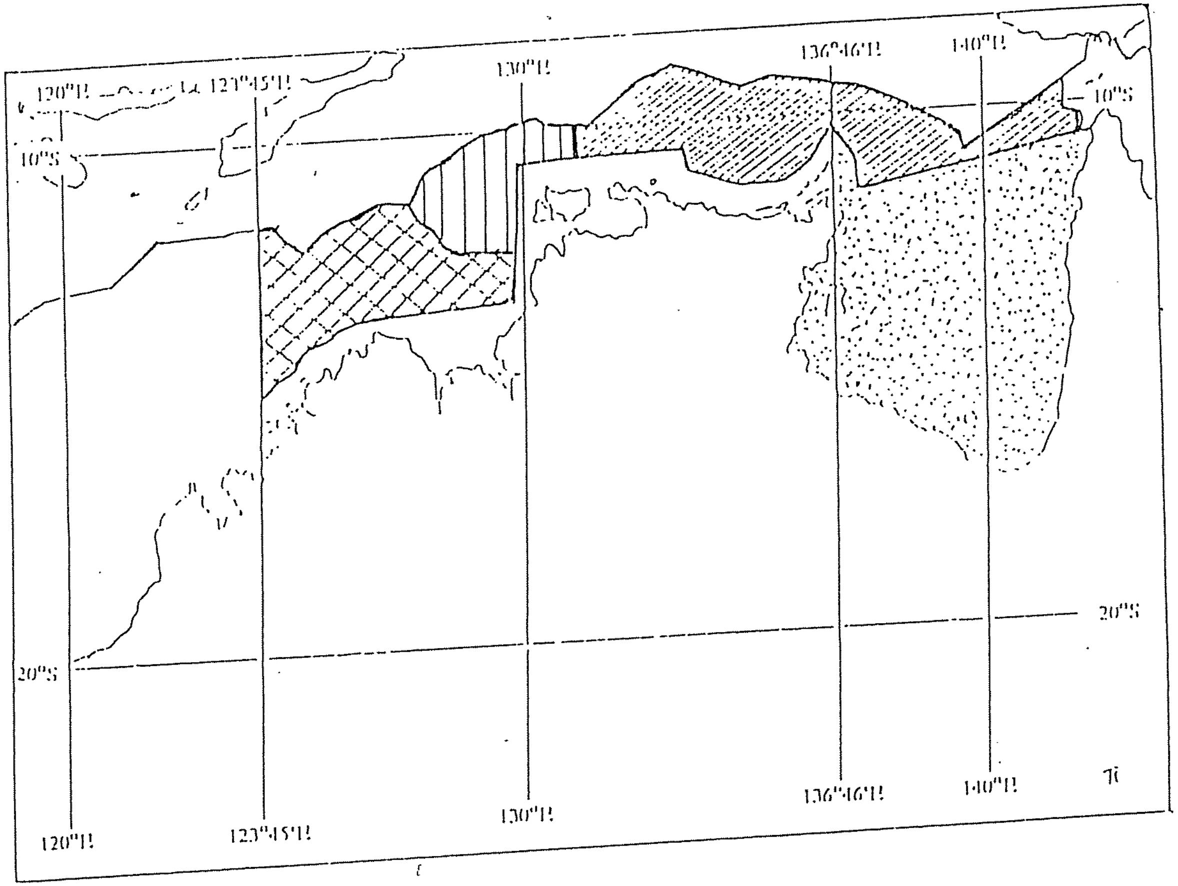
1991
ZONES



LEGEND	TAC
GOC Zone	not yet determined
Timor Trap & Line	no fish trawling
Timor Sea Zone	1,200 tonnes
Arafura Sea Zone	2,000 tonnes

Figure 1.1 [illegible] Access Zones

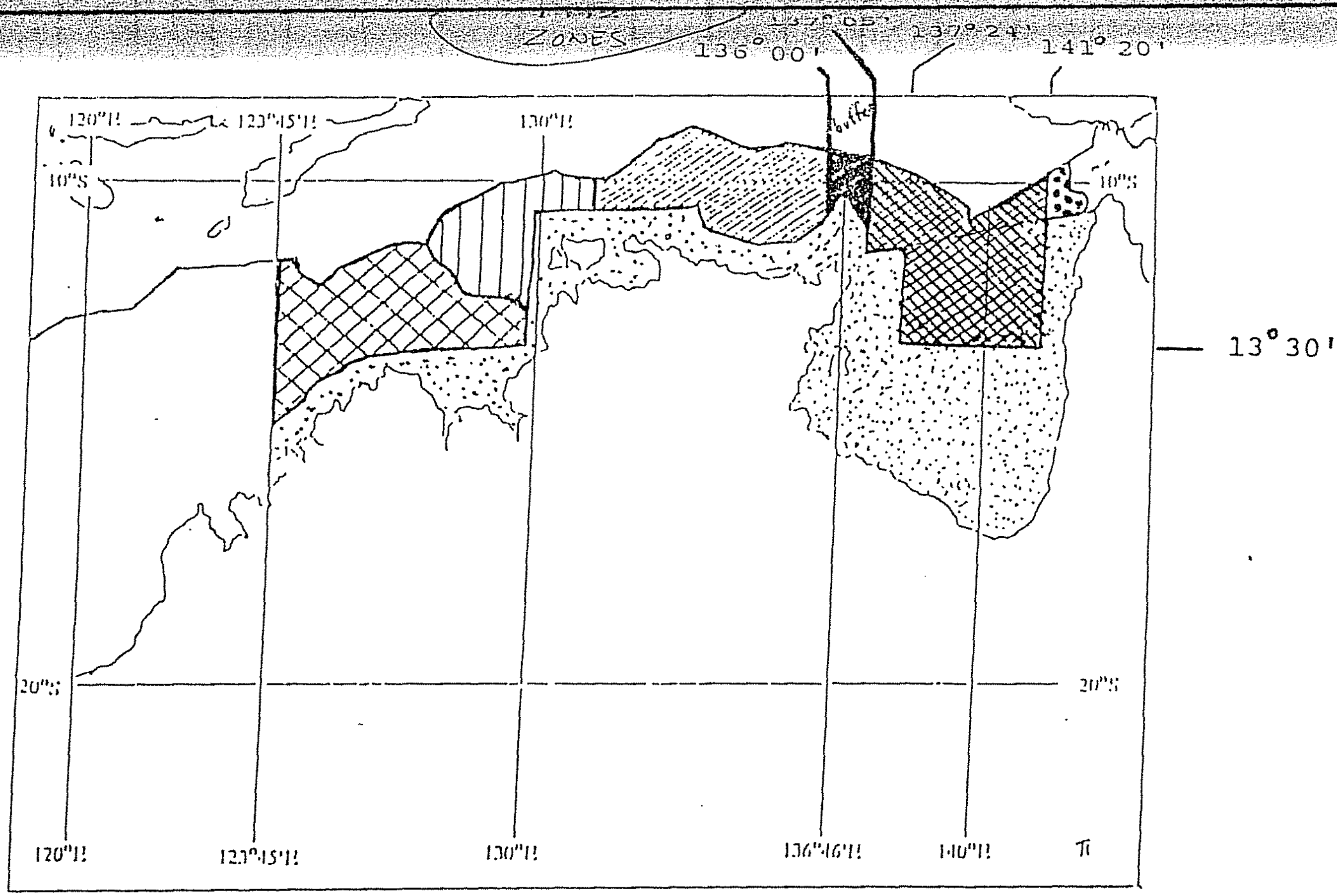


Figure 1.2 Proposed 1992 Access Zones

LEGEND	TAC
NPF Seasonal Closure	–
Timor Trap & Line	no fish trawling
Timor Sea Zone	tonnes
Arafura Sea Zone	tonnes
Wessel Trap & Line	no fish trawling
GOC Zone	tonnes
T. St Buffer	no fish trawling.

Table 3.b.1

Summary of AFZ logbook data files for foreign and domestic fleets.

Fleet	Year	Nos Records	%Records Accepted
Taiwanese	1980	26007	99.0
	1981	19333	99.0
	1982	24972	99.0
	1983	28286	99.0
	1984	35386	99.0
	1985	22942	99.0
	1986	14659	99.0
	1987	4697	99.0
	1988	4721	99.6
	1989	4465	98.8
	1990	1030	99.3
Thai	1985	736	97.6
	1986	4877	99.2
	1987	6991	99.6
	1988	8349	99.4
	1989	14846	99.5
	1990	9952	99.7
Chinese	1989	3053	35.0
Domestic	1987	111	25.2
	1988	440	45.2
	1989	0	0
	1990	384	24.0
	1991	892	76.6 (incomplete)

Saddle Tail Snapper (*Lutjanus malabaricus*)

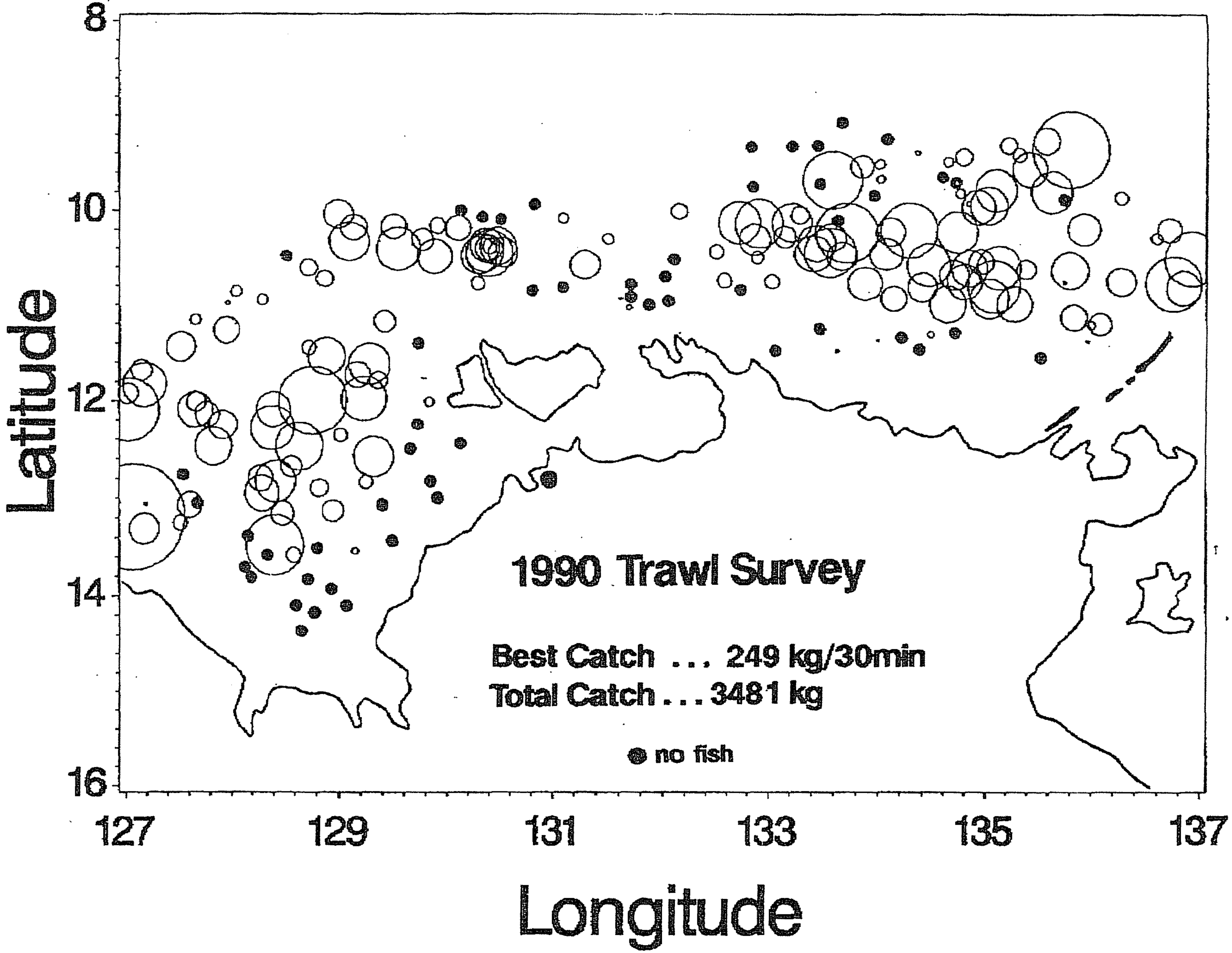
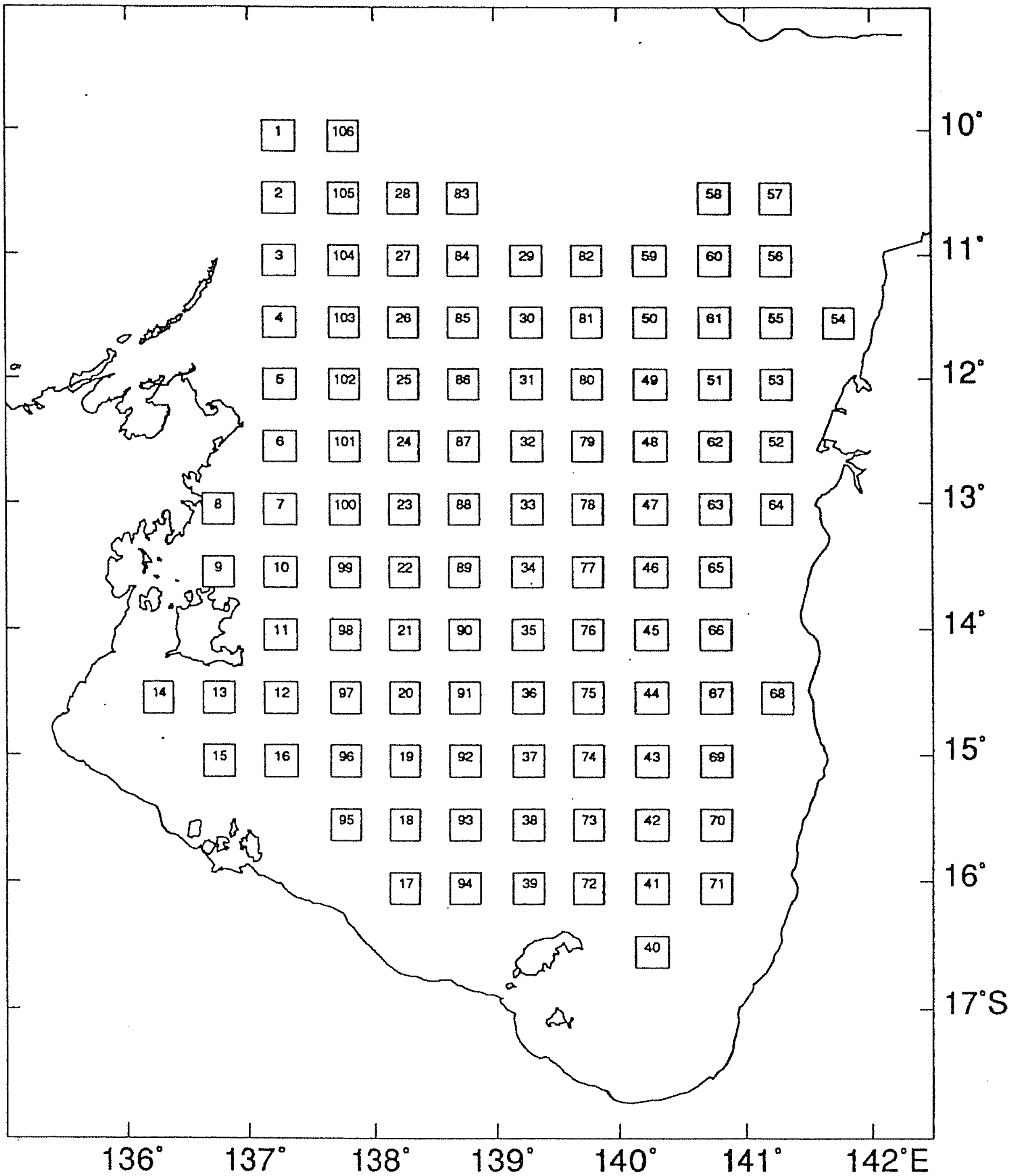


Figure 3.d.ii.1. Grids sampled in the 1990 CSIRO trawl survey.



Distribution and abundance: *L.malabaricus*, scarlet perch

(Kg h^{-1})

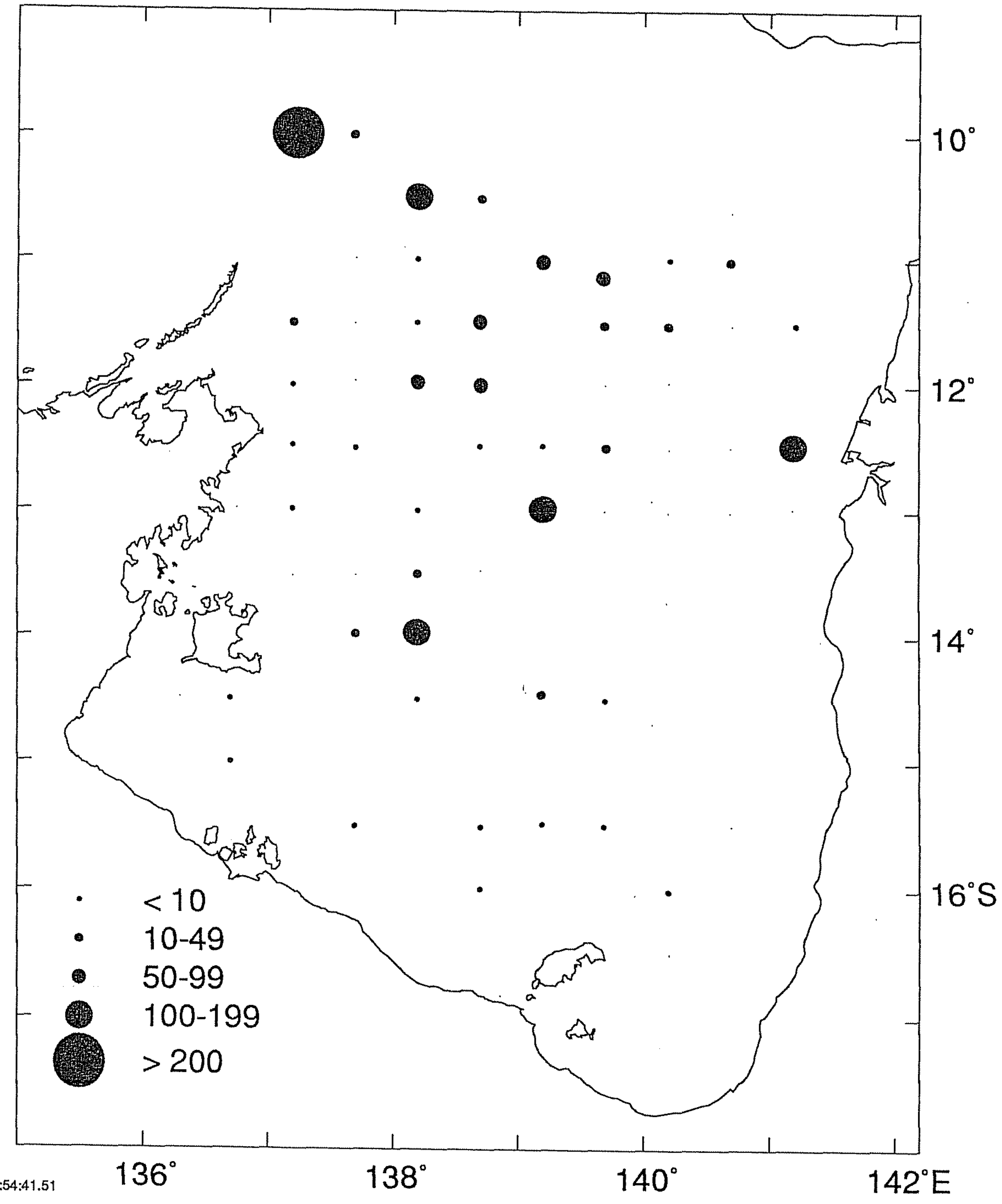


Table 3d1

Biomass of *Lutjanus malabaricus* (a), SN3 (b), and all species (c) in the Timor and Arafura Seas between 127-137oE based on data from the 1990 NT survey. The survey covered an area of [illegible]066[illegible]0km2 (n=207). The SN3 category included: *L.malabaricus*, *L.erythropterus*, *L.sebae*, and *L.timorensis*. The all species category included: teleosts and elasmobranchs (98.3% by weight) and benthic invertebrates (1.7% by weight).

(a) *Lutjanus malabaricus*

ESTIMATED BIOMASS (x000 t)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	594.6	297.3	198.2	148.6	118.9	99.1	84.9	74.3	66.1	59.5
25	475.7	237.8	158.6	118.9	95.1	79.3	68.0	59.5	52.9	47.6
30	396.4	198.2	132.1	99.1	79.3	66.1	56.6	49.5	44.0	39.6
35	339.8	169.9	113.3	84.9	68.0	56.6	48.5	42.5	37.8	34.0
40	297.3	148.6	99.1	74.3	59.5	49.5	42.5	37.2	33.0	29.7
45	264.3	132.1	88.1	66.1	52.9	44.0	37.8	33.0	29.4	26.4
50	237.8	118.9	79.3	59.5	47.6	39.6	34.0	29.7	26.4	23.8
55	216.2	108.1	72.1	54.1	43.2	36.0	30.9	27.0	24.0	21.6
60	198.2	99.1	66.1	49.5	39.6	33.0	28.3	24.8	22.0	19.8
65	182.9	91.5	61.0	45.7	36.6	30.5	26.1	22.9	20.3	18.3
70	169.9	84.9	56.6	42.5	34.0	28.3	24.3	21.2	18.9	17.0
75	158.6	79.3	52.9	39.6	31.7	26.4	22.7	19.8	17.6	15.9

STANDARD ERROR (x000 t)

Width	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	69.7	34.8	23.2	17.4	13.9	11.6	10.0	8.7	7.7	7.0
25	55.7	27.9	18.6	13.9	11.1	9.3	8.0	7.0	6.2	5.6
30	46.4	23.2	15.5	11.6	9.3	7.7	6.6	5.8	5.2	4.6
35	39.8	19.9	13.3	10.0	8.0	6.6	5.7	5.0	4.4	4.0
40	34.8	17.4	11.6	8.7	7.0	5.8	5.0	4.4	3.9	3.5
45	31.0	15.5	10.3	7.7	6.2	5.2	4.4	3.9	3.4	3.1
50	27.9	13.9	9.3	7.0	5.6	4.6	4.0	3.5	3.1	2.8
55	25.3	12.7	8.4	6.3	5.1	4.2	3.6	3.2	2.8	2.5
60	23.2	11.6	7.7	5.8	4.6	3.9	3.3	2.9	2.6	2.3
65	21.4	10.7	7.1	5.4	4.3	3.6	3.1	2.7	2.4	2.1
70	19.9	10.0	6.6	5.0	4.0	3.3	2.8	2.5	2.2	2.0
75	18.6	9.3	6.2	4.6	3.7	3.1	2.7	2.3	2.1	1.9

Table 3d1 (cont...)

(b) SN3 Biomass 127-137oE

ESTIMATED BIOMASS (x000 t)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	728.9	364.5	243.0	182.2	145.8	121.5	104.1	91.1	81.0	72.9
25	583.1	291.6	194.4	145.8	116.6	97.2	83.3	72.9	64.8	58.3
30	485.9	243.0	162.0	121.5	97.2	81.0	69.4	60.7	54.0	48.6
35	416.5	208.3	138.8	104.1	83.3	69.4	59.5	52.1	46.3	41.7
40	364.5	182.2	121.5	91.1	72.9	60.7	52.1	45.6	40.5	36.4
45	324.0	162.0	108.0	81.0	64.8	54.0	46.3	40.5	36.0	32.4
50	291.6	145.8	97.2	72.9	58.3	48.6	41.7	36.4	32.4	29.2
55	265.1	132.5	88.4	66.3	53.0	44.2	37.9	33.1	29.5	26.5
60	243.0	121.5	81.0	60.7	48.6	40.5	34.7	30.4	27.0	24.3
65	224.3	112.1	74.8	56.1	44.9	37.4	32.0	28.0	24.9	22.4
70	208.3	104.1	69.4	52.1	41.7	34.7	29.8	26.0	23.1	20.8
75	194.4	97.2	64.8	48.6	38.9	32.4	27.8	24.3	21.6	19.4

STANDARD ERROR (x000 t)

Width	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	77.4	38.7	25.8	19.3	15.5	12.9	11.1	9.7	8.6	7.7
25	61.9	31.0	20.6	15.5	12.4	10.3	8.8	7.7	6.9	6.2
30	51.6	25.8	17.2	12.9	10.3	8.6	7.4	6.4	5.7	5.2
35	44.2	22.1	14.7	11.1	8.8	7.4	6.3	5.5	4.9	4.4
40	38.7	19.3	12.9	9.7	7.7	6.4	5.5	4.8	4.3	3.9
45	34.4	17.2	11.5	8.6	6.9	5.7	4.9	4.3	3.8	3.4
50	31.0	15.5	10.3	7.7	6.2	5.2	4.4	3.9	3.4	3.1
55	28.1	14.1	9.4	7.0	5.6	4.7	4.0	3.5	3.1	2.8
60	25.8	12.9	8.6	6.4	5.2	4.3	3.7	3.2	2.9	2.6
65	23.8	11.9	7.9	6.0	4.8	4.0	3.4	3.0	2.6	2.4
70	22.1	11.1	7.4	5.5	4.4	3.7	3.2	2.8	2.5	2.2
75	20.6	10.3	6.9	5.2	4.1	3.4	2.9	2.6	2.3	2.1

Table 3d1 (cont...)

(c) All species Biomass 127-137oE

ESTIMATED BIOMASS (x000 t)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	8328	4164	2776	2082	1665	1388	1189	1041.1	925.4	832.9
25	6662	3331	2221	1665	1332	1110.5	951.8	832.9	740.3	666.3
30	5552	2776	1850	1388	1110.5	925.4	793.2	694.1	616.9	555.2
35	4759	2379	1586	1189.8	951.8	793.2	679.9	594.9	528.8	475.9
40	4164	2082	1388	1041.1	832.9	694.1	594.9	520.5	462.7	416.4
45	3701	1850	1233.9	925.4	740.3	616.9	528.8	462.7	411.3	370.2
50	3331	1665	1110.5	832.9	666.3	555.2	475.9	416.4	370.2	333.1
55	3028	1514	1009.5	757.2	605.7	504.8	432.7	378.6	336.5	302.9
60	2776	1388.1	925.4	694.1	555.2	462.7	396.6	347.0	308.5	277.6
65	2562	1281.3	854.2	640.7	512.5	427.1	366.1	320.3	284.7	256.3
70	2379	1189.8	793.2	594.9	475.9	396.6	339.9	297.5	264.4	238.0
75	2221	1110.5	740.3	555.2	444.2	370.2	317.3	277.6	246.8	222.1

STANDARD ERROR (x000 t)

Width	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	572.8	286.4	190.9	143.2	114.6	95.5	81.8	71.6	63.6	57.3
25	458.2	229.1	152.7	114.6	91.6	76.4	65.5	57.3	50.9	45.8
30	381.9	190.9	127.3	95.5	76.4	63.6	54.6	47.7	42.4	38.2
35	327.3	163.7	109.1	81.8	65.5	54.6	46.8	40.9	36.4	32.7
40	286.4	143.2	95.5	71.6	57.3	47.7	40.9	35.8	31.8	28.6
45	254.6	127.3	84.9	63.6	50.9	42.4	36.4	31.8	28.3	25.5
50	229.1	114.6	76.4	57.3	45.8	38.2	32.7	28.6	25.5	22.9
55	208.3	104.1	69.4	52.1	41.7	34.7	29.8	26.0	23.1	20.8
60	190.9	95.5	63.6	47.7	38.2	31.8	27.3	23.9	21.2	19.1
65	176.2	88.1	58.7	44.1	35.2	29.4	25.2	22.0	19.6	17.6
70	163.7	81.8	54.6	40.9	32.7	27.3	23.4	20.5	18.2	16.4
75	152.7	76.4	50.9	38.2	30.5	25.5	21.8	19.1	17.0	15.3

Tables 3d2 (a) to (d). Biomass and standard error estimates of (a) *Lutjanus malabaricus*, (b) large red lutjanids (SN3s) and all fishes (day (c) and night (d)) in the Gulf of Carpentaria based on data from the CSIRO 1990 survey (Fig. 3.d.ii.1). All fishes includes teleosts and elasmobranchs.

Table 3d2 (a)

Lutjanus malabaricus

GULF OF CARPENTARIA SURVEY AREA

Area = 336720 km^2
No. obs. = 105
No. non-zero obs. = 41

ESTIMATED BIOMASSES (* 000 t)

Trawl Retention Options

NET WIDTH (M)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	390.4	195.2	130.1	97.6	78.1	65.1	55.8	48.8	43.4	39.0
25	312.3	156.2	104.1	78.1	62.5	52.1	44.6	39.0	34.7	31.2
30	260.3	130.1	86.8	65.1	52.1	43.4	37.2	32.5	28.9	26.0
35	223.1	111.5	74.4	55.8	44.6	37.2	31.9	27.9	24.8	22.3
40	195.2	97.6	65.1	48.8	39.0	32.5	27.9	24.4	21.7	19.5
45	173.5	86.8	57.8	43.4	34.7	28.9	24.8	21.7	19.3	17.4
50	156.1	78.1	52.1	39.0	31.2	26.0	22.3	19.5	17.4	15.6
55	142.0	71.0	47.3	35.5	28.4	23.7	20.3	17.7	15.8	14.2
60	130.1	65.1	43.4	32.5	26.0	21.7	18.6	16.3	14.5	13.0
65	120.1	60.1	40.0	30.0	24.0	20.0	17.2	15.0	13.4	12.0
70	111.5	55.8	37.2	27.9	22.3	18.6	15.9	13.9	12.4	11.2
75	104.1	52.1	34.7	26.0	20.8	17.4	14.9	13.0	11.6	10.4

42 18.2

STANDARD ERRORS (* 000 t)

Trawl Retention Options

NET WIDTH (M)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	109.0	54.5	36.3	27.3	21.8	18.2	15.6	13.6	12.1	10.9
25	87.2	43.6	29.1	21.8	17.4	14.5	12.5	10.9	9.7	8.7
30	72.7	36.3	24.2	18.2	14.5	12.1	10.4	9.1	8.1	7.3
35	62.3	31.2	20.8	15.6	12.5	10.4	8.9	7.8	6.9	6.2
40	54.5	27.3	18.2	13.6	10.9	9.1	7.8	6.8	6.1	5.5
45	48.5	24.2	16.2	12.1	9.7	8.1	6.9	6.1	5.4	4.9
50	43.6	21.8	14.5	10.9	8.7	7.3	6.2	5.5	4.9	4.4
55	39.7	19.8	13.2	9.9	7.9	6.6	5.7	5.0	4.4	4.0
60	36.3	18.2	12.1	9.1	7.3	6.1	5.2	4.5	4.0	3.6
65	33.6	16.8	11.2	8.4	6.7	5.6	4.8	4.2	3.7	3.4
70	31.2	15.6	10.4	7.8	6.2	5.2	4.5	3.9	3.5	3.1
75	29.1	14.5	9.7	7.3	5.8	4.9	4.2	3.6	3.2	2.9

± 5.2

Table 3d2 (b)

Red snappers

GULF OF CARPENTARIA SURVEY AREA

Area = 336720 km^2
No. obs. = 105
No. non-zero obs. = 45

ESTIMATED BIOMASSES (* 000 t)

Trawl Retention Options

NET WIDTHS (M)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	351.1	175.5	117.0	87.8	70.2	58.5	50.2	43.9	39.0	35.1
25	280.9	140.4	93.6	70.2	56.2	46.8	40.1	35.1	31.2	28.1
30	234.1	117.0	78.0	58.5	46.8	39.0	33.4	29.3	26.0	23.4
35	200.6	100.3	66.9	50.2	40.1	33.4	28.7	25.1	22.3	20.1
40	187.8	58.5	43.9	35.1	29.3	25.1	21.9	19.5	17.6	17.9
45	156.0	78.0	52.0	39.0	31.2	26.0	22.3	19.5	17.3	15.6
50	140.4	70.2	46.8	35.1	28.1	23.4	20.1	17.6	15.6	14.0
55	127.7	63.8	42.6	31.9	25.5	21.3	18.2	16.0	14.2	12.8
60	117.0	58.5	39.0	29.3	23.4	19.5	16.7	14.6	13.0	11.7
65	108.0	54.0	36.0	27.0	21.6	18.0	15.4	13.5	12.0	10.8
70	100.3	50.2	33.4	25.1	20.1	16.7	14.3	12.5	11.2	10.0
75	93.6	46.8	31.2	23.4	18.7	15.6	13.4	11.7	10.4	9.4

STANDARD ERRORS (* 000 t)

Trawl Retention Options

NET WIDTHS (M)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	89.2	44.6	29.7	22.3	17.9	14.9	12.8	11.2	9.9	8.9
25	71.4	35.7	23.8	17.9	14.3	11.9	10.2	8.9	7.9	7.1
30	59.5	29.7	19.8	14.9	11.9	9.9	8.5	7.4	6.6	6.0
35	51.0	25.5	17.0	12.8	10.2	8.5	7.3	6.4	5.7	5.1
40	44.6	22.3	14.9	11.2	8.9	7.4	6.4	5.6	5.0	4.5
45	39.7	19.8	13.2	9.9	7.9	6.6	5.7	5.0	4.4	4.0
50	35.7	17.8	11.9	8.9	7.1	6.0	5.1	4.5	4.0	3.6
55	32.5	16.2	10.8	8.1	6.5	5.4	4.6	4.1	3.6	3.3
60	29.7	14.9	9.9	7.4	6.0	5.0	4.3	3.7	3.3	3.0
65	27.5	13.7	9.2	6.9	5.5	4.6	3.9	3.4	3.1	2.7
70	25.5	12.8	8.5	6.4	5.1	4.3	3.6	3.2	2.8	2.6
75	23.8	11.9	7.9	6.0	4.8	4.0	3.4	3.0	2.6	2.4

Table 3d2 (c)

All fishes

GULF OF CARPENTARIA SURVEY AREA: DAY ONLY

Area = 336720 km^2
No. obs. = 46
No. non-zero obs. = 46

ESTIMATED BIOMASSES (* 000 t)

Trawl Retention Options

NET WIDTHS (M)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	11732.5	5866.3	3910.8	2933.1	2346.5	1955.4	1676.1	1466.6	1303.6	1173.3
25	9386.0	4693.0	3128.7	2346.5	1877.2	1564.3	1340.9	1173.3	1042.9	938.6
30	7821.7	3910.8	2607.2	1955.4	1564.3	1303.6	1117.4	977.7	869.1	782.2
35	6704.3	3352.1	2234.8	1676.1	1340.9	1117.4	957.8	838.0	744.9	670.4
40	5866.3	2933.1	1955.4	1466.6	1173.3	977.7	838.0	733.3	651.8	586.6
45	5214.3	2607.1	1738.1	1303.6	1042.9	869.0	744.9	651.8	579.4	521.4
50	4692.9	2346.4	1564.3	1173.2	938.6	782.1	670.4	586.6	521.4	469.3
55	4266.2	2133.1	1422.1	1066.6	853.3	711.0	609.5	533.3	474.0	426.6
60	3910.7	1955.4	1303.6	977.7	782.2	651.8	558.7	488.8	434.5	391.1
65	3609.9	1805.0	1203.3	902.5	722.0	601.7	515.7	451.2	401.1	361.0
70	3352.1	1676.0	1117.4	838.0	670.4	558.7	478.9	419.0	372.5	335.2
75	3128.6	1564.3	1042.9	782.2	625.7	521.4	446.9	391.1	347.6	312.9

STANDARD ERRORS (* 000 t)

Trawl Retention Options

NET WIDTHS (M)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	3569.5	1784.8	1189.8	892.4	713.9	594.9	509.9	446.2	396.6	357.0
25	2855.6	1427.8	951.9	713.9	571.1	475.9	407.9	357.0	317.3	285.6
30	2379.7	1189.8	793.2	594.9	475.9	396.6	340.0	297.5	264.4	238.0
35	2039.7	1019.9	679.9	509.9	407.9	340.0	291.4	255.0	226.6	204.0
40	1784.8	892.4	594.9	446.2	357.0	297.5	255.0	223.1	198.3	178.5
45	1586.4	793.2	528.8	396.6	317.3	264.4	226.6	198.3	176.3	158.6
50	1427.8	713.9	475.9	356.9	285.6	238.0	204.0	178.5	158.6	142.8
55	1298.0	649.0	432.7	324.5	259.6	216.3	185.4	162.3	144.2	129.8
60	1189.8	594.9	396.6	297.5	238.0	198.3	170.0	148.7	132.2	119.0
65	1098.3	549.1	366.1	274.6	219.7	183.1	156.9	137.3	122.0	109.8
70	1019.8	509.9	340.0	255.0	204.0	170.0	145.7	127.5	113.3	102.0
75	951.9	475.9	317.3	238.0	190.4	158.6	136.0	119.0	105.8	95.2

Table 3d2 (d)

All fishes

GULF OF CARPENTARIA SURVEY AREA: NIGHT ONLY

Area = 336720 km^2
No. obs. = 59
No. non-zero obs. = 59

ESTIMATED BIOMASSES (* 000 t)

NET WIDTHS (M)	Trawl Retention Options 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	5576.1	2788.1	1858.7	1394.0	1115.2	929.4	796.6	697.0	619.6	557.6
25	4460.9	2230.5	1487.0	1115.2	892.2	743.5	637.3	557.6	495.7	446.1
30	3717.4	1858.7	1239.1	929.4	743.5	619.6	531.1	464.7	413.1	371.7
35	3186.4	1593.2	1062.1	796.6	637.3	531.1	455.2	398.3	354.0	318.6
40	2788.1	1394.0	929.4	697.0	557.6	464.7	398.3	348.5	309.8	278.8
45	2478.2	1239.1	826.1	619.6	495.6	413.0	354.0	309.8	275.4	247.8
50	2230.4	1115.2	743.5	557.6	446.1	371.7	318.6	278.8	247.8	223.0
55	2027.6	1013.8	675.9	506.9	405.5	337.9	289.7	253.5	225.3	202.8
60	1858.7	929.3	619.6	464.7	371.7	309.8	265.5	232.3	206.5	185.9
65	1715.7	857.9	571.9	428.9	343.1	286.0	245.1	214.5	190.6	171.6
70	1593.2	796.6	531.1	398.3	318.6	265.5	227.6	199.1	177.0	159.3
75	1486.9	743.5	495.7	371.7	297.4	247.8	212.4	185.9	165.2	148.7

STANDARD ERRORS (* 000 t)

NET WIDTHS (M)	Trawl Retention Options 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	624.9	312.4	208.3	156.2	125.0	104.1	89.3	78.1	69.4	62.5
25	499.9	250.0	166.6	125.0	100.0	83.3	71.4	62.5	55.5	50.0
30	416.6	208.3	138.9	104.1	83.3	69.4	59.5	52.1	46.3	41.7
35	357.1	178.5	119.0	89.3	71.4	59.5	51.0	44.6	39.7	35.7
40	312.4	156.2	104.1	78.1	62.5	52.1	44.6	39.1	34.7	31.2
45	277.7	138.9	92.6	69.4	55.5	46.3	39.7	34.7	30.9	27.8
50	249.9	125.0	83.3	62.5	50.0	41.7	35.7	31.2	27.8	25.0
55	227.2	113.6	75.7	56.8	45.4	37.9	32.5	28.4	25.3	22.7
60	208.3	104.1	69.4	52.1	41.7	34.7	29.8	26.0	23.1	20.8
65	192.3	96.1	64.1	48.1	38.5	32.0	27.5	24.0	21.4	19.2
70	178.5	89.3	59.5	44.6	35.7	29.8	25.5	22.3	19.8	17.9
75	166.6	83.3	55.5	41.7	33.3	27.8	23.8	20.8	18.5	16.7

4a1. CATCH AND EFFORT DATA FOR THE ARAFURA SEA (131-142E)

ffort(hours),catch(t) as (I4,1X,F6.0,10(1X,F6.1))

ESE DATA

E(hrs)	catch(t)	nemi	saur	butt	cara	serr	leth	l.lu	s.lu	haem
2854.	1255.0	165.3	49.3	0.	0.	0.	0.	234.3	0.	0.
17425.	8164.8	2109.9	395.9	0.	0.	0.	0.	1401.5	0.	0.
19334.	9535.9	2811.2	907.2	0.	0.	0.	0.	1157.9	0.	0.
19083.	8817.3	2596.9	1190.3	0.	0.	0.	0.	770 5	0.	0.
14412.	5089.5	1371.0	233.5	0.	0.	0.	58.9	841.4	28.2	0.
18208.	6025.7	1560.3	453.9	0.	0.	0.	116.0	907.4	53.4	0.
25951.	9150.3	1266.4	219.6	0.	0.	0.	83.4	911.7	76.7	0.
29250.	7688.9	1130.3	162.2	0.	0.	0.	221.3	684.8	95.2	0.
23544.	6073.4	783.5	123.4	0.	0.	0.	230.4	426.9	46.3	0.
17724.	7180.4	1121.6	66.8	212.2	687.[illegible]	19.6	112.6	1084.0	30.2	235.9
9970.	4215.0	651.8	109.6	133.2	344.1	5.8	67.9	860.1	73.6	91.0
14088.	5919.0	666.1	49.1	1078.5	621.7	12.0	89.9	1018.0	157.4	202.4
28505.	9982.5	741.9	18.4	3442.1	719.0	22.8	180.4	2334.4	95.3	284.4
30239.	8625.8	434.7	9.6	364.1	917.1	51.6	366.6	3240.8	302.6	498.8
7245.	2511.4	211.8	26.7	320.1	197.0	5.7	55.7	807.8	84.5	83.0
17031.	5313.5	546.7	37.0	1091.1	253.7	16.6	217.0	1582.5	143.0	161.9
3982.	1255.0	162.3	9.4	65.8	95.7	4.8	80.3	434.5	49.1	38.6
2717.	723.3	96.3	4.5	82.9	7.0	1.3	35.1	262.6	17.0	9.0
22.	4.1	0.0	0.0	0.0	0.0	0.0	0.4	3.5	0.1	0.0
1508.	413.0	19.3	4.6	42.1	2.9	3.6	28.8	169.5	15.4	0.0

DATA

E(hrs)	catch(t)	nemi	saur	butt	cara	serr	leth	l.lu	s.lu	haem
2660.	353.8	19.7	6.6	0.0	15.3	3.3	18.1	138.9	12.0	13.8
17935.	2766.6	154.0	51.4	0.0	120.0	25.8	141.5	1086.2	93.8	108.2
25761.	3682.5	205.0	68.4	0.0	159.7	34.4	188.4	1445.8	124.8	144.0
31439.	4408.0	277.5	37.7	0.0	346.6	48.4	255.7	2268.1	145.9	215.2
61238.	7956.5	276.5	103.2	0.0	685.5	98.7	478.7	4265.9	229.9	400.9
41697.	5436.1	229.6	136.9	0.0	435.5	59.1	273.4	2613.3	185.8	309.5

IC DATA

E(hrs)	catch(t)	nemi	saur	butt	cara	serr	leth	l.lu	s.lu	haem
556.	52.2	0.0	0.0	0.0	1.7	0.0	0.0	44.2	0.4	2.8
2266.	200.4	0.0	0.0	0.0	9.1	1.0	4.1	152.4	0.0	10.5
0.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1826.	136.5	0.0	0.0	0.0	0.0	0.2	8.3	117.1	1.2	0.8
3110.	352.1	0.0	0.0	0.0	0.0	0.2	5.5	324.5	0.8	7.3

BLE 4a2. COMBINED CATCH AND STANDARDISED EFFORT DATA FOR THE ARAFURA SEA

eet1 = Taiwanese
eet2 = Thai
eet3 = Domestic

TOTAL CATCH

YEAR	TOTAL CATCH	STD EFFORT	TOTAL CPUE	RATIO2	RATIO3	RETAIN
1971	1255.	2854.	.4397	.000	.000	1.00
1972	8164.	17425.	.4685	.000	.000	1.00
1973	9535.	19334.	.4932	.000	.000	1.00
1974	8817.	19083.	.4620	.000	.000	1.00
1975	5089.	14412.	.3531	.000	.000	1.00
1976	6025.	18208.	.3309	.000	.000	1.00
1977	9150.	25951.	.3526	.000	.000	1.00
1978	7688.	29250.	.2628	.000	.000	1.00
1979	6073.	23544.	.2579	.000	.000	1.00
1980	7180.	17724.	.4051	.000	.000	1.00
1981	4215.	9970.	.4228	.000	.000	1.00
1982	5919.	14088.	.4201	.000	.000	1.00
1983	9982.	28505.	.3502	.000	.000	1.00
1984	8625.	30239.	.2852	.000	.000	1.00
1985	2864.	8264.	.3466	.383	.000	1.00
1986	8079.	25898.	.3120	.494	.000	1.00
1987	4989.	15830.	.3152	.454	.297	1.00
1988	5331.	20034.	.2661	.527	.332	1.00
1989	7960.	30763.	.2588	.502	.000	1.00
1990	5985.	21853.	.2739	.476	.272	1.00

ERAGE CATCH=.665E+04 AVERAGE EFFORT=.196E+05

ERE STD EFFORT = SUM(EFFORT*RATIOX) ACROSS FLEETS
AND RATIOX = (CPUE FLEET X)/(CPUE FLEET 1)

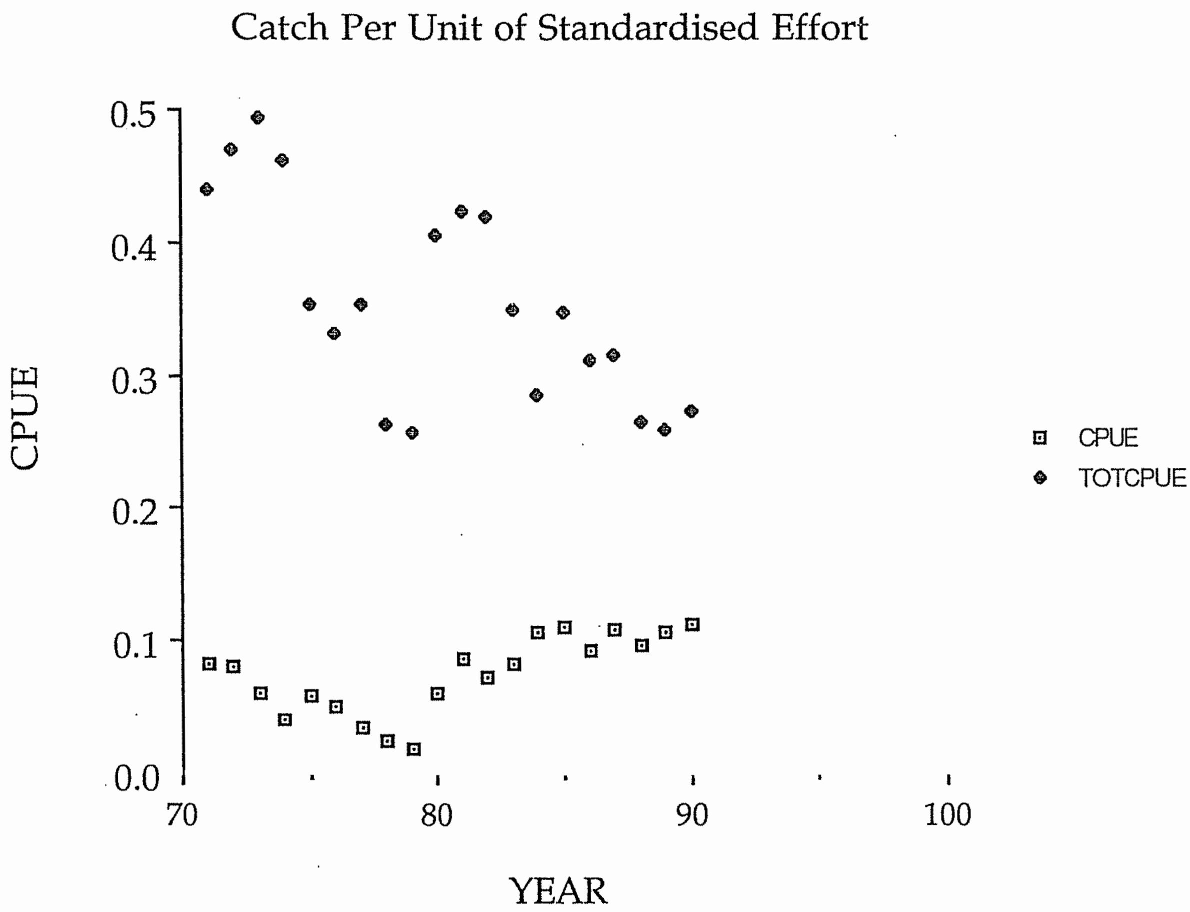
LARGE LUTJANUS

YEAR	TOTAL CATCH	STD EFFORT	TOTAL CPUE	RATIO2	RATIO3	RETAIN
1971	234.	2854.	.0820	.000	.000	1.00
1972	1401.	17425.	.0804	.000	.000	1.00
1973	1157.	19334.	.0598	.000	.000	1.00
1974	770.	19083.	.0404	.000	.000	1.00
1975	841.	14412.	.0584	.000	.000	1.00
1976	907.	18208.	.0498	.000	.000	1.00
1977	911.	25951.	.0351	.000	.000	1.00
1978	684.	29250.	.0234	.000	.000	1.00
1979	426.	23544.	.0181	.000	.000	1.00
1980	1084.	17724.	.0612	.000	.000	1.00
1981	860.	9970.	.0863	.000	.000	1.00
1982	1018.	14088.	.0723	.000	.000	1.00
1983	2334.	28505.	.0819	.000	.000	1.00
1984	3240.	30239.	.1071	.000	.000	1.00
1985	945.	8484.	.1114	.466	.000	1.00
1986	2668.	28722.	.0929	.652	.000	1.00
1987	1923.	17644.	.1090	.515	.726	1.00
1988	2682.	27813.	.0964	.748	.696	1.00
1989	4268.	40041.	.1364	.654	.000	1.00
1990	2899.	25868.	.1121	.559	.572	1.00

ERAGE CATCH=.156E+04 AVERAGE EFFORT=.209E+05

HERE STD EFFORT = SUM(EFFORT*RATIOX) ACROSS FLEETS
AND RATIOX = (CPUE FLEET X)/(CPUE FLEET 1)

FIGURE 4A1. CATCH PER EFFORT FOR ARAFURA SEA DATA



where TOTCPUE = CPUE for total catch, and
CPUE = CPUE for large lutjanus

4b1 RESULTS OF SURPLUS PRODUCTION ANALYSIS FOR ARAFURA SEA
COMMERCIAL CATEGORY SN3 - LARGE LUTJNUS

ASS CALCULATED USING THE LOGISTIC SURPLUS PRODUCTION MODEL
+1)=B(T)*(1+R-R*B(T)/K-Q*E(T))
(T)=Q*E(T)*B(T)*D
D=PROPORTION OF CATCH RETAINED

ORTION OF CATCH RETAINED HAS FORM
(T)=Do*(1+AA*T) T=YEARS SINCE START OF FISHING
Do=1.00 AA= .00

CHABILITY COEFFICIENT HAS FORM
)=Q T<To
(T)=Q(1+S+A*(T-To)) T>To
RE To= 1979

YEAR	TOTAL CATCH	STD EFFORT	CPUE
1971	234.	2854.	.0820
1972	1401.	17425.	.0804
1973	1157.	19334.	.0598
1974	770.	19083.	.0404
1975	841.	14412.	.0584
1976	91.	18208.	.0050
1977	911.	25951.	.0351
1978	684.	29250.	.0234
1979	426.	23544.	.0181
1980	1084.	17724.	.0612
1981	860.	9970.	.0863
1982	1018.	14088.	.0723
1983	2334.	28505.	.0819
1984	3240.	30239.	.1071
1985	945.	8484.	.1114
1986	2668.	28722.	.0929
1987	1923.	17644.	.1090
1988	2682.	27813.	.0964
1989	4268.	40041.	.1066
1990	2899.	25868.	.1121

ERAGE CATCH=.152E+04 AVERAGE EFFORT=.210E+05

HERE STD EFFORT = SUM(EFFORT*RATIOX) ACROSS FLEETS WHERE
RATIOX IS COMPARISON OF CPUE OF FLEET X WITH FLEET 1

RID SEARCH TO MINIMIZE THE LIKELIHOOD FUNCTION
SUM(LOG(C(T)/PREDC))**2
TO BE CARRIED OUT ACROSS THE FOLLOWING VALUES

A	S	Q	R	K
.000E+00	.000E+00	.700E-07	.100E-01	.140E+05
.190E+00	.170E+00	.150E-06	.600E-01	.200E+05
.380E+00	.340E+00	.115E-05	.115E+00	.260E+05
.570E+00	.522E+00	.215E-05	.160E+00	.324E+05
.760E+00	.680E+00	.315E-05	.210E+00	.380E+05
.950E+00	.850E+00	.415E-05	.260E+00	.440E+05
.114E+01	.102E+01	.515E-05	.310E+00	.500E+05
.133E+01	.119E+01	.615E-05	.370E+00	.560E+05

IMUM OF LIKELIHOOD FUNCTION = 6.1802 WHERE

380E+00 S=.522E+00 Q=.115E-05 R=.115E+00 K=.324E+05

95% CONFIDENCE REGION ON THE LIKELIHOOD SURFACE IS GIVEN BY VALVES
LOG(LIKELIHOOD) < 10.80

CENTAGE OF POINTS WITHIN CRITICAL REGION= 9.2

% OF BOUNDARY OF A IN THE CRITICAL REGION
% OF BOUNDARY OF S IN THE CRITICAL REGION
% OF BOUNDARY OF Q IN THE CRITICAL REGION
% OF BOUNDARY OF R IN THE CRITICAL REGION
% OF BOUNDARY OF K IN THE CRITICAL REGION

CTED BIOMASS AND CATCHES USING ABOVE EFFORT AND THE
US PRODUCTION MODEL

YEAR	BIOMASS	CATCH	PRED CATCH	SKILL
1971	32400.	234.	106.	1.00
1972	32294.	1401.	647.	1.00
1973	31659.	1157.	704.	1.00
1974	31038.	770.	681.	1.00
1975	30506.	841.	506.	1.00
1976	30205.	91.	632.	1.00
1977	29806.	911.	890.	1.00
1978	29190.	684.	982.	1.00
1979	28539.	426.	773.	1.00
1980	28156.	1084.	1092.	1.90
1981	27487.	860.	719.	2.28
1982	27245.	1018.	1175.	2.66
1983	26566.	2334.	2649.	3.04
1984	24464.	3240.	2911.	3.42
1985	22239.	945.	825.	3.80
1986	22212.	2668.	3068.	4.18
1987	19944.	1923.	1846.	4.56
1988	18975.	2682.	3000.	4.94
1989	16876.	4268.	4136.	5.32
1990	13666.	2899.	2318.	5.70
1991	12252.			6.08

```
 VS. YEAR     * =CATCH TAKEN    + =PREDICTED CATCH

     1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.
I---------|---------|---------|---------|---------|---------|---------|---------|
|+*
|     +       *
|      +    *
|      +*
|    +  *
|*    +
|        E
|      *  +
|   *   +
|          E
|      + *
|         * +
|                      *  +
|                            +  *
|       +*
|                          *   +
|                 +*
|                          *  +
|                                        + *
|                      +     *
```

UM SUSTAINABLE YIELD=   927. TONNES
T AT MSY=   8730. HOURS WITH 1990 Q
T AT MSY=   8185. HOURS WITH 1991 Q
TED BIOMASS AT START OF 1991, B= 12252. TONNES
CTED CATCH COEFFICIENT FOR 1991, Q= .115E-05
CTED FISHING MORTALITY FOR 1991, F= .010

```
LATION OF MSY AND 1991 BIOMASS DISTRIBUTIONS

NCE OF NORMAL ERROR= .1225

G VALUES FOUND WITHIN CRITICAL REGION WEIGHTED BY LIKELIHOOD
MSY=      1385.   STD DEVIATION=      758.

UENCY OF VALUES
                                 20        40        60        80       100
M     TO        %   ---------|---------|---------|---------|---------|
65.-    578.  20. **********
577.-  1089.  26. *************
088.-  1601.  20. **********
600.-  2112.  18. *********
111.-  2624.   7. ****
623.-  3135.   5. **
134.-  3647.   3. *
646.-  4158.   1. *
157.-  4670.   1.
669.-  5181.   0.

RIBUTION OF LIKELIHOOD
                                 .2        .4        .6        .8       1.0
M     TO        %   ---------|---------|---------|---------|---------|
65.-    578.  20. **********
577.-  1089.  21. **********
088.-  1601.  23. ***********
600.-  2112.  23. ************
111.-  2624.   8. ****
623.-  3135.   5. **
134.-  3647.   1.
646.-  4158.   0.
157.-  4670.   0.
669.-  5181.   0.

G VALUES FOUND WITHIN CRITICAL REGION WEIGHTED BY LIKELIHOOD
ASS AT START OF 1991=     12958.   STD DEVIATION=      5918.

UENCY OF VALUES
                                 20        40        60        80       100
M     TO        %   ---------|---------|---------|---------|---------|
405.-  5399.  41. ********************
398.- 10392.  22. ***********
391.- 15385.  13. ******
384.- 20378.   8. ****
377.- 25371.   6. ***
370.- 30365.   4. **
364.- 35358.   3. *
357.- 40351.   2. *
350.- 45344.   1. *
343.- 50337.   1.

RIBUTION OF LIKELIHOOD
                                 .2        .4        .6        .8       1.0
M     TO        %   ---------|---------|---------|---------|---------|
405.-  5399.   9. ****
398.- 10392.  30. ***************
391.- 15385.  28. **************
384.- 20378.  20. **********
377.- 25371.  12. ******
370.- 30365.   2. *
364.- 35358.   0.
357.- 40351.   0.
350.- 45344.   0.
343.- 50337.   0.
```

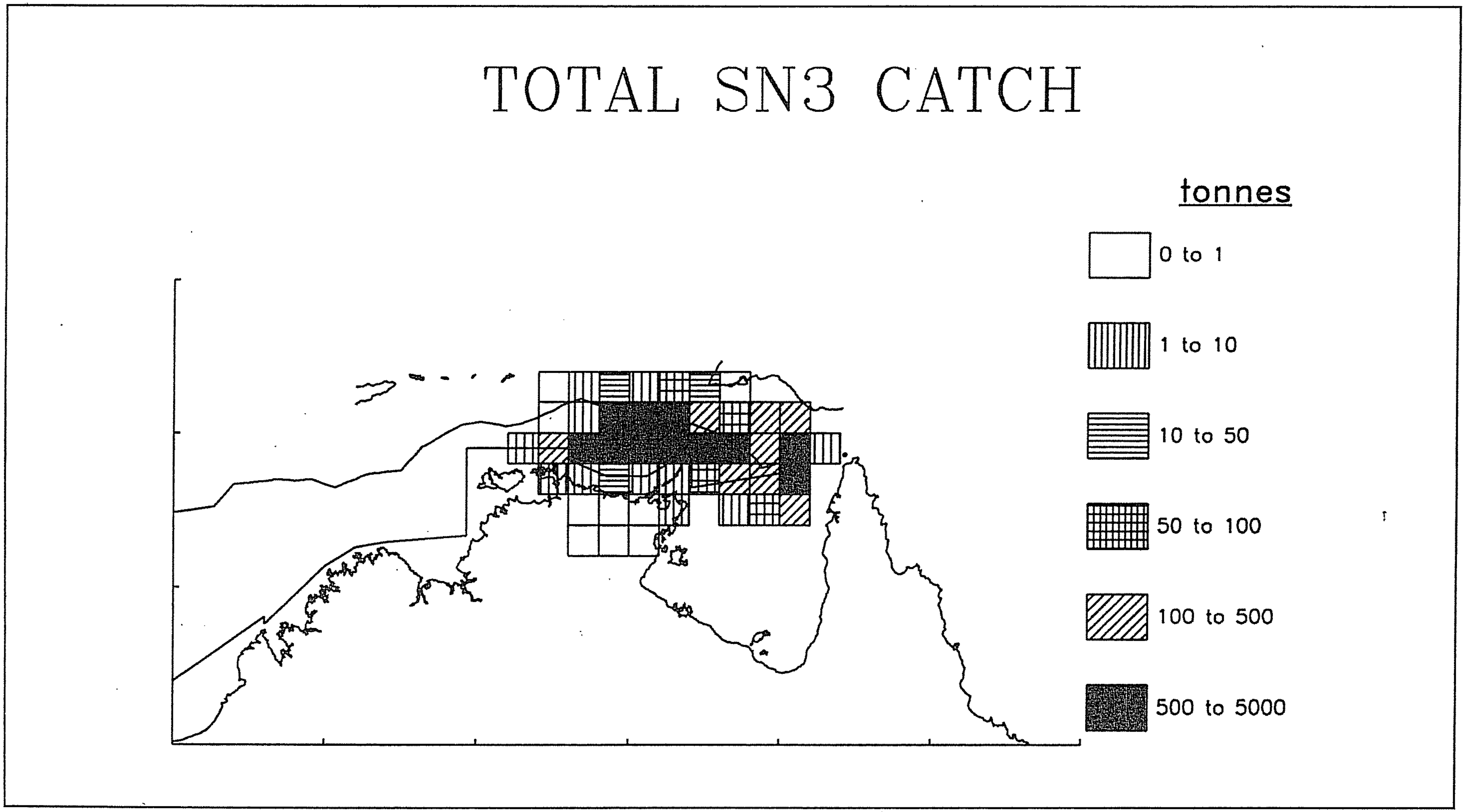
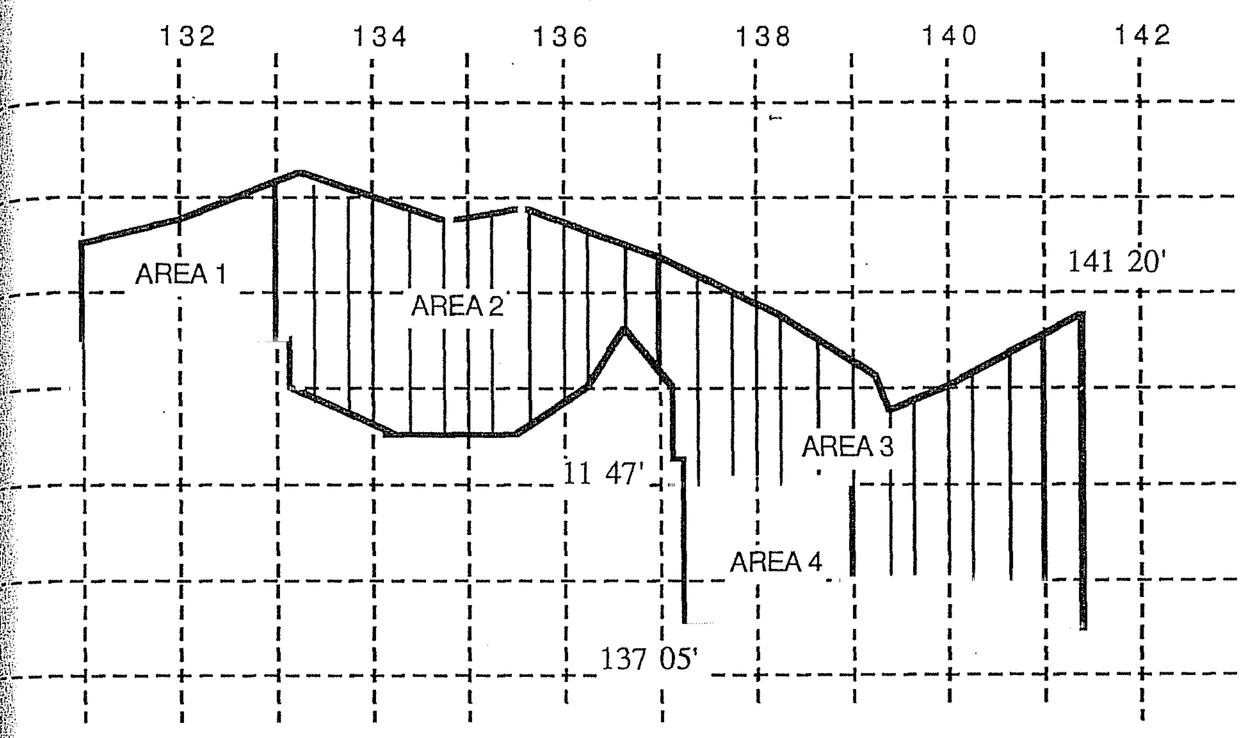
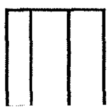


Figure 4C1 Spatial Distribution of Commercial Catch of SN3 (1971-90)

FIGURE 4c2 DEFINITION OF AREAS USED IN ANALYSIS





= EXTENT OF MAJOR HISTORICAL FISHING GROUNDS

AREA 1 = 31,000 KM2 DENSITY 1 = 0.071 TONNES/KM2

AREA 2 = 88,000 KM2 DENSITY 2 = 0.145 TONNES/KM2

AREA 3 =102,000 KM2 DENSITY 3 = 0.131 TONNES/KM2

AREA 4 = 52,000 KM2 DENSITY 4 = 0.066 TONNES/KM2

WHERE DENSITY IS DENSITY OF LARGE LUTJANUS

Table 4 C1

Biomass of *Lutjanus malabaricus* (a) and SN3 (b) in the Arafura Sea management zone between 131-137o based on data from the 1990 NT survey (n=80).

(a) *Lutjanus malabaricus*

ESTIMATED BIOMASS (x000 t)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	281.5	140.7	93.8	70.4	56.3	46.9	40.2	35.2	31.3	28.1
25	225.2	112.6	75.1	56.3	45.0	37.5	32.2	28.1	25.0	22.5
30	187.7	93.8	62.6	46.9	37.5	31.3	26.8	23.5	20.9	18.8
35	160.8	80.4	53.6	40.2	32.2	26.8	23.0	20.1	17.9	16.1
40	140.7	70.4	46.9	35.2	28.1	23.5	20.1	17.6	15.6	14.1
45	125.1	62.6	41.7	31.3	25.0	20.9	17.9	15.6	13.9	12.5
50	112.6	56.3	37.5	28.1	22.5	18.8	16.1	14.1	12.5	11.3
55	102.4	51.2	34.1	25.6	20.5	17.1	14.6	12.8	11.4	10.2
60	93.8	46.9	31.3	23.5	18.8	15.6	13.4	11.7	10.4	9.4
65	86.6	43.3	28.9	21.7	17.3	14.4	12.4	10.8	9.6	8.7
70	80.4	40.2	26.8	20.1	16.1	13.4	11.5	10.1	8.9	8.0
75	75.1	37.5	25.0	18.8	15.0	12.5	10.7	9.4	8.3	7.5

STANDARD ERROR (x000 t)

Width	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	37.5	18.7	12.5	9.4	7.5	6.2	5.4	4.7	4.2	3.7
25	30.0	15.0	10.0	7.5	6.0	5.0	4.3	3.7	3.3	3.0
30	25.0	12.5	8.3	6.2	5.0	4.2	3.6	3.1	2.8	2.5
35	21.4	10.7	7.1	5.4	4.3	3.6	3.1	2.7	2.4	2.1
40	18.7	9.4	6.2	4.7	3.7	3.1	2.7	2.3	2.1	1.9
45	16.7	8.3	5.6	4.2	3.3	2.8	2.4	2.1	1.9	1.7
50	15.0	7.5	5.0	3.7	3.0	2.5	2.1	1.9	1.7	1.5
55	13.6	6.8	4.5	3.4	2.7	2.3	1.9	1.7	1.5	1.4
60	12.5	6.2	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.2
65	11.5	5.8	3.8	2.9	2.3	1.9	1.6	1.4	1.3	1.2
70	10.7	5.4	3.6	2.7	2.1	1.8	1.5	1.3	1.2	1.1
75	10.0	5.0	3.3	2.5	2.0	1.7	1.4	1.2	1.1	1.0

Table 4Ci (cont...)

(b) SN3

ESTIMATED BIOMASS (x000 t)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	361.7	180.8	120.6	90.4	72.3	60.3	51.7	45.2	40.2	36.2
25	289.3	144.7	96.4	72.3	57.9	48.2	41.3	36.2	32.1	28.9
30	241.1	120.6	80.4	60.3	48.2	40.2	34.4	30.1	26.8	24.1
35	206.7	103.3	68.9	51.7	41.3	34.4	29.5	25.8	23.0	20.7
40	180.8	90.4	60.3	45.2	36.2	30.1	25.8	22.6	20.1	18.1
45	160.7	80.4	53.6	40.2	32.1	26.8	23.0	20.1	17.9	16.1
50	144.7	72.3	48.2	36.2	28.9	24.1	20.7	18.1	16.1	14.5
55	131.5	65.8	43.8	32.9	26.3	21.9	18.8	16.4	14.6	13.2
60	120.6	60.3	40.2	30.1	24.1	20.1	17.2	15.1	13.4	12.1
65	111.3	55.6	37.1	27.8	22.3	18.5	15.9	13.9	12.4	11.1
70	103.3	51.7	34.4	25.8	20.7	17.2	14.8	12.9	11.5	10.3
75	96.4	48.2	32.1	24.1	19.3	16.1	13.8	12.1	10.7	9.6

STANDARD ERROR (x000 t)

Width	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	48.4	24.2	16.1	12.1	9.7	8.1	6.9	6.1	5.4	4.8
25	38.7	19.4	12.9	9.7	7.7	6.5	5.5	4.8	4.3	3.9
30	32.3	16.1	10.8	8.1	6.5	5.4	4.6	4.0	3.6	3.2
35	27.7	13.8	9.2	6.9	5.5	4.6	4.0	3.5	3.1	2.8
40	24.2	12.1	8.1	6.1	4.8	4.0	3.5	3.0	2.7	2.4
45	21.5	10.8	7.2	5.4	4.3	3.6	3.1	2.7	2.4	2.2
50	19.4	9.7	6.5	4.8	3.9	3.2	2.8	2.4	2.2	1.9
55	17.6	8.8	5.9	4.4	3.5	2.9	2.5	2.2	2.0	1.8
60	16.1	8.1	5.4	4.0	3.2	2.7	2.3	2.0	1.8	1.6
65	14.9	7.4	5.0	3.7	3.0	2.5	2.1	1.9	1.7	1.5
70	13.8	6.9	4.6	3.5	2.8	2.3	2.0	1.7	1.5	1.4
75	12.9	6.5	4.3	3.2	2.6	2.2	1.8	1.6	1.4	1.3

Tables 4C2 (a) & (b). Biomass and standard error estimates of (a) Lutjanus malabaricus, (b) large red lutjanids (SN3s) in the Gulf of Carpentaria management zone based on data from the CSIRO 1990 survey (Fig. 3.d.ii.1). All fishes includes teleosts and elasmobranchs.

Table 4

Lutjanus malabaricus

GULF OF CARPENTARIA MANAGEMENT ZONE

Area: 154963 km^2
No.obs. = 52
No.non-zero obs. = 25

ESTIMATED BIOMASSES (* 000 t)

NET WIDTHS (M)	Trawl Retention Options									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	325.1	162.6	108.4	81.3	65.0	54.2	46.4	40.6	36.1	32.5
25	260.1	130.0	86.7	65.0	52.0	43.4	37.2	32.5	28.9	26.0
30	216.7	108.4	72.2	54.2	43.4	36.1	31.0	27.1	24.1	21.7
35	185.8	92.9	61.9	46.4	37.2	31.0	26.5	23.2	20.6	18.6
40	162.6	81.3	54.2	40.6	32.5	27.1	23.2	20.3	18.1	16.3
45	144.5	72.2	48.2	36.1	28.9	24.1	20.6	18.1	16.1	14.5
50	130.0	65.0	43.3	32.5	26.0	21.7	18.6	16.3	14.5	13.0
55	118.2	59.1	39.4	29.6	23.6	19.7	16.9	14.8	13.1	11.8
60	108.4	54.2	36.1	27.1	21.7	18.1	15.5	13.6	12.0	10.8
65	100.0	50.0	33.3	25.0	20.0	16.7	14.3	12.5	11.1	10.0
70	92.9	46.4	31.0	23.2	18.6	15.5	13.3	11.6	10.3	9.3
75	86.7	43.3	28.9	21.7	17.3	14.5	12.4	10.8	9.6	8.7

STANDARD ERRORS (* 000 t)

NET WIDTHS (M)	Trawl Retention Options									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	94.5	47.3	31.5	23.6	18.9	15.8	13.5	11.8	10.5	9.5
25	75.6	37.8	25.2	18.9	15.1	12.6	10.8	9.5	8.4	7.6
30	63.0	31.5	21.0	15.8	12.6	10.5	9.0	7.9	7.0	6.3
35	54.0	27.0	18.0	13.5	10.8	9.0	7.7	6.8	6.0	5.4
40	47.3	23.6	15.8	11.8	9.5	7.9	6.8	5.9	5.3	4.7
45	42.0	21.0	14.0	10.5	8.4	7.0	6.0	5.3	4.7	4.2
50	37.8	18.9	12.6	9.5	7.6	6.3	5.4	4.7	4.2	3.8
55	34.4	17.2	11.5	8.6	6.9	5.7	4.9	4.3	3.8	3.4
60	31.5	15.8	10.5	7.9	6.3	5.3	4.5	3.9	3.5	3.2
65	29.1	14.5	9.7	7.3	5.8	4.9	4.2	3.6	3.2	2.9
70	27.0	13.5	9.0	6.8	5.4	4.5	3.9	3.4	3.0	2.7
75	25.2	12.6	8.4	6.3	5.0	4.2	3.6	3.2	2.8	2.5

Table 4.C2(b)

Red Snappers

GULF OF CARPENTARIA MANAGEMENT ZONE

Area = km²
No. obs. = 52
No. non-zero obs. = 26

ESTIMATED BIOMASSES (* 000 t)

Trawl Retention Options

NET WIDTHS (M)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	387.4	193.7	129.1	96.9	77.5	64.6	55.3	48.4	43.1	38.7
25	309.9	155.0	103.3	77.5	62.0	51.7	44.3	38.7	34.4	31.0
30	258.3	129.1	86.1	64.6	51.7	43.1	36.9	32.3	28.7	25.8
35	221.4	110.7	73.8	55.3	44.3	36.9	31.6	27.7	24.6	22.1
40	193.7	96.9	64.6	48.4	38.7	32.3	27.7	24.2	21.5	19.4
45	172.2	86.1	57.4	43.0	34.4	28.7	24.6	21.5	19.1	17.2
50	155.0	77.5	51.7	38.7	31.0	25.8	22.1	19.4	17.2	15.5
55	140.9	70.4	47.0	35.2	28.2	23.5	20.1	17.6	15.7	14.1
60	129.1	64.6	43.0	32.3	25.8	21.5	18.5	16.1	14.4	12.9
65	119.2	59.6	39.7	29.8	23.8	19.9	17.0	14.9	13.2	11.9
70	110.7	55.3	36.9	27.7	22.1	18.5	15.8	13.8	12.3	11.1
75	103.3	51.7	34.4	25.8	20.7	17.2	14.8	12.9	11.5	10.3

STANDARD ERRORS (* 000 t)

Trawl Retention Options

NET WIDTHS (M)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	101.0	50.5	33.7	25.3	20.2	16.8	14.4	12.6	11.2	10.1
25	80.8	40.4	26.9	20.2	16.2	13.5	11.5	10.1	9.0	8.1
30	67.3	33.7	22.4	16.8	13.5	11.2	9.6	8.4	7.5	6.7
35	57.7	28.9	19.2	14.4	11.5	9.6	8.3	7.2	6.4	5.8
40	50.5	25.3	16.8	12.6	10.1	8.4	7.2	6.3	5.6	5.1
45	44.9	22.4	15.0	11.2	9.0	7.5	6.4	5.6	5.0	4.5
50	40.4	20.2	13.5	10.1	8.1	6.7	5.8	5.1	4.5	4.0
55	36.7	18.4	12.2	9.2	7.3	6.1	5.2	4.6	4.1	3.7
60	33.7	16.8	11.2	8.4	6.7	5.6	4.8	4.2	3.7	3.4
65	31.1	15.5	10.4	7.8	6.2	5.2	4.4	3.9	3.5	3.1
70	28.9	14.4	9.6	7.2	5.8	4.8	4.1	3.6	3.2	2.9
75	26.9	13.5	9.0	6.7	5.4	4.5	3.9	3.4	3.0	2.7

Table 4d1

Density of SN3 in the Arafura Sea management zone between longitudes 133-137oE (a), 131-<133oE (b), and 131-137oE (c) based on data from the 1990 NT survey. Historical fishing grounds are between 133-137oE, and the management zone is between 131-137oE.

(a) SN3 Density Arafura Sea 133-137oE (n=70)

ESTIMATED DENSITY (kg/km2)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	3256.8	1628.4	1085.6	814.2	651.4	542.8	465.3	407.1	361.9	325.7
25	2605.4	1302.7	868.5	651.4	521.1	434.2	372.2	325.7	289.5	260.5
30	2171.2	1085.6	723.7	542.8	434.2	361.9	310.2	271.4	241.2	217.1
35	1861.0	930.5	620.3	465.3	372.2	310.2	265.9	232.6	206.8	186.1
40	1628.4	814.2	542.8	407.1	325.7	271.4	232.6	203.6	180.9	162.8
45	1447.5	723.7	482.5	361.9	289.5	241.2	206.8	180.9	160.8	144.7
50	1302.7	651.4	434.2	325.7	260.5	217.1	186.1	162.8	144.7	130.3
55	1184.3	592.1	394.8	296.1	236.9	197.4	169.2	148.0	131.6	118.4
60	1085.6	542.8	361.9	271.4	217.1	180.9	155.1	135.7	120.6	108.6
65	1002.1	501.0	334.0	250.5	200.4	167.0	143.2	125.3	111.3	100.2
70	930.5	465.3	310.2	232.6	186.1	155.1	132.9	116.3	103.4	93.1
75	868.5	434.2	289.5	217.1	173.7	144.7	124.1	108.6	96.5	86.8

STANDARD ERROR (kg/km2)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	451.4	225.7	150.5	112.9	90.3	75.2	64.5	56.4	50.2	45.1
25	361.1	180.6	120.4	90.3	72.2	60.2	51.6	45.1	40.1	36.1
30	301.0	150.5	100.3	75.2	60.2	50.2	43.0	37.6	33.4	30.1
35	258.0	129.0	86.0	64.5	51.6	43.0	36.9	32.2	28.7	25.8
40	225.7	112.9	75.2	56.4	45.1	37.6	32.2	28.2	25.1	22.6
45	200.6	100.3	66.9	50.2	40.1	33.4	28.7	25.1	22.3	20.1
50	180.6	90.3	60.2	45.1	36.1	30.1	25.8	22.6	20.1	18.1
55	164.2	82.1	54.7	41.0	32.8	27.4	23.5	20.5	18.2	16.4
60	150.5	75.2	50.2	37.6	30.1	25.1	21.5	18.8	16.7	15.0
65	138.9	69.5	46.3	34.7	27.8	23.2	19.8	17.4	15.4	13.9
70	129.0	64.5	43.0	32.2	25.8	21.5	18.4	16.1	14.3	12.9
75	120.4	60.2	40.1	30.1	24.1	20.1	17.2	15.0	13.4	12.0

Table 4d1 (cont...)

(b) SN3 Density Arafura Sea 131-<133oE (n=10)

ESTIMATED DENSITY (kg/km2)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	1598.7	799.4	532.9	399.7	319.7	266.5	228.4	199.8	177.6	159.9
25	1279.0	639.5	426.3	319.7	255.8	213.2	182.7	159.9	142.1	127.9
30	1065.8	532.9	355.3	266.5	213.2	177.6	152.3	133.2	118.4	106.6
35	913.5	456.8	304.5	228.4	182.7	152.3	130.5	114.2	101.5	91.4
40	799.4	399.7	266.5	199.8	159.9	133.2	114.2	99.9	88.8	79.9
45	710.5	355.3	236.8	177.6	142.1	118.4	101.5	88.8	78.9	71.1
50	639.5	319.7	213.2	159.9	127.9	106.6	91.4	79.9	71.1	63.9
55	581.3	290.7	193.8	145.3	116.3	96.9	83.0	72.7	64.6	58.1
60	532.9	266.5	177.6	133.2	106.6	88.8	76.1	66.6	59.2	53.3
65	491.9	246.0	164.0	123.0	98.4	82.0	70.3	61.5	54.7	49.2
70	456.8	228.4	152.3	114.2	91.4	76.1	65.3	57.1	50.8	45.7
75	426.3	213.2	142.1	106.6	85.3	71.1	60.9	53.3	47.4	42.6

STANDARD ERROR (kg/km2)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	701.4	350.7	233.8	175.3	140.3	116.9	100.2	87.7	77.9	70.1
25	561.1	280.5	187.0	140.3	112.2	93.5	80.2	70.1	62.3	56.1
30	467.6	233.8	155.9	116.9	93.5	77.9	66.8	58.4	52.0	46.8
35	400.8	200.4	133.6	100.2	80.2	66.8	57.3	50.1	44.5	40.1
40	350.7	175.3	116.9	87.7	70.1	58.4	50.1	43.8	39.0	35.1
45	311.7	155.9	103.9	77.9	62.3	52.0	44.5	39.0	34.6	31.2
50	280.5	140.3	93.5	70.1	56.1	46.8	40.1	35.1	31.2	28.1
55	255.0	127.5	85.0	63.8	51.0	42.5	36.4	31.9	28.3	25.5
60	233.8	116.9	77.9	58.4	46.8	39.0	33.4	29.2	26.0	23.4
65	215.8	107.9	71.9	54.0	43.2	36.0	30.8	27.0	24.0	21.6
70	200.4	100.2	66.8	50.1	40.1	33.4	28.6	25.0	22.3	20.0
75	187.0	93.5	62.3	46.8	37.4	31.2	26.7	23.4	20.8	18.7

Table 4d1 (cont...)

(c) SN3 Density Arafura Sea 131-137oE (n=80)

ESTIMATED DENSITY (kg/km2)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	3049.5	1524.8	1016.5	762.4	609.9	508.3	435.6	381.2	338.8	305.0
25	2439.6	1219.8	813.2	609.9	487.9	406.6	348.5	305.0	271.1	244.0
30	2033.0	1016.5	677.7	508.3	406.6	338.8	290.4	254.1	225.9	203.3
35	1742.6	871.3	580.9	435.6	348.5	290.4	248.9	217.8	193.6	174.3
40	1524.8	762.4	508.3	381.2	305.0	254.1	217.8	190.6	169.4	152.5
45	1355.4	677.7	451.8	338.8	271.1	225.9	193.6	169.4	150.6	135.5
50	1219.8	609.9	406.6	305.0	244.0	203.3	174.3	152.5	135.5	122.0
55	1108.9	554.5	369.6	277.2	221.8	184.8	158.4	138.6	123.2	110.9
60	1016.5	508.3	338.8	254.1	203.3	169.4	145.2	127.1	112.9	101.7
65	938.3	469.2	312.8	234.6	187.7	156.4	134.0	117.3	104.3	93.8
70	871.3	435.6	290.4	217.8	174.3	145.2	124.5	108.9	96.8	87.1
75	813.2	406.6	271.1	203.3	162.6	135.5	116.2	101.7	90.4	81.3

STANDARD ERROR (kg/km2)

Trawl	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	408.1	204.1	136.0	102.0	81.6	68.0	58.3	51.0	45.3	40.8
25	326.5	163.2	108.8	81.6	65.3	54.4	46.6	40.8	36.3	32.6
30	272.1	136.0	90.7	68.0	54.4	45.3	38.9	34.0	30.2	27.2
35	233.2	116.6	77.7	58.3	46.6	38.9	33.3	29.2	25.9	23.3
40	204.1	102.0	68.0	51.0	40.8	34.0	29.2	25.5	22.7	20.4
45	181.4	90.7	60.5	45.3	36.3	30.2	25.9	22.7	20.2	18.1
50	163.2	81.6	54.4	40.8	32.6	27.2	23.3	20.4	18.1	16.3
55	148.4	74.2	49.5	37.1	29.7	24.7	21.2	18.6	16.5	14.8
60	136.0	68.0	45.3	34.0	27.2	22.7	19.4	17.0	15.1	13.6
65	125.6	62.8	41.9	31.4	25.1	20.9	17.9	15.7	14.0	12.6
70	116.6	58.3	38.9	29.2	23.3	19.4	16.7	14.6	13.0	11.7
75	108.8	54.4	36.3	27.2	21.8	18.1	15.5	13.6	12.1	10.9

Tables 4d2 Density and standard error estimates of large red lutjanids (SN3s) in the historical fishing area (eastern zone) based on data from the CSIRO 1990 survey (Fig. 3.d.ii.1). All fishes includes teleosts and elasmobranchs.

Table 4d2

Red Snappers

DENSITY IN THE HISTORICAL FISHING AREA
(EASTERN ZONE)

Area:104955km2
No. obs. = 27
No. non-zero obs. = 14

DENSITY (kgs/km^2)

NET WIDTHS (M)	Trawl Retention Options 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	2951.9	1475.9	984.0	738.0	590.4	492.0	421.7	369.0	328.0	295.2
25	2361.5	1180.8	787.2	590.4	472.3	393.6	337.4	295.2	262.4	236.2
30	1967.9	984.0	656.0	492.0	393.6	328.0	281.1	246.0	218.7	196.8
35	1686.8	843.4	562.3	421.7	337.4	281.1	241.0	210.9	187.4	168.7
40	1475.9	738.0	492.0	369.0	295.2	246.0	210.9	184.5	164.0	147.6
45	1311.9	656.0	437.3	328.0	262.4	218.7	187.4	164.0	145.8	131.2
50	1180.7	590.4	393.6	295.2	236.1	196.8	168.7	147.6	131.2	118.1
55	1073.4	536.7	357.8	268.3	214.7	178.9	153.3	134.2	119.3	107.3
60	983.9	492.0	328.0	246.0	196.8	164.0	140.6	123.0	109.3	98.4
65	908.3	454.1	302.8	227.1	181.7	151.4	129.8	113.5	100.9	90.8
70	843.4	421.7	281.1	210.8	168.7	140.6	120.5	105.4	93.7	84.3
75	787.2	393.6	262.4	196.8	157.4	131.2	112.5	98.4	87.5	78.7

STANDARD ERROR (kgs/km^2)

NET WIDTHS (M)	Trawl Retention Options 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	849.1	424.6	283.0	212.3	169.8	141.5	121.3	106.1	94.4	84.9
25	679.3	339.6	226.4	169.8	135.9	113.2	97.0	84.9	75.5	67.9
30	566.1	283.0	188.7	141.5	113.2	94.4	80.9	70.8	62.9	56.6
35	485.2	242.6	161.7	121.3	97.0	80.9	69.3	60.7	53.9	48.5
40	424.6	212.3	141.5	106.1	84.9	70.8	60.7	53.1	47.2	42.5
45	377.4	188.7	125.8	94.3	75.5	62.9	53.9	47.2	41.9	37.7
50	339.6	169.8	113.2	84.9	67.9	56.6	48.5	42.5	37.7	34.0
55	308.8	154.4	102.9	77.2	61.8	51.5	44.1	38.6	34.3	30.9
60	283.0	141.5	94.3	70.8	56.6	47.2	40.4	35.4	31.5	28.3
65	261.3	130.6	87.1	65.3	52.3	43.5	37.3	32.7	29.0	26.1
70	242.6	121.3	80.9	60.7	48.5	40.4	34.7	30.3	27.0	24.3
75	226.4	113.2	75.5	56.6	45.3	37.7	32.4	28.3	25.2	22.6

Table 4d2 (b)

Red Snappers

DENSITY IN THE UNFISHED AREA (AREA 4)

DENSITY (kg/km2)

H	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
0	1482.1	741.0	494.0	370.5	296.4	247.0	211.7	185.3	164.7	148.2
5	1185.6	592.8	395.2	296.4	237.1	197.6	169.4	148.2	131.7	118.6
0	988.0	494.0	329.4	247.0	197.6	164.7	141.2	123.5	109.8	98.8
5	846.9	423.4	282.3	211.7	169.4	141.2	121.0	105.9	94.1	84.7
0	741.0	370.5	247.0	185.3	148.2	123.5	105.9	92.6	82.3	74.1
5	658.7	329.3	219.6	164.7	131.7	109.8	94.1	82.3	73.2	65.9
0	592.8	296.4	197.6	148.2	118.6	98.8	84.7	74.1	65.9	59.3
5	538.9	269.5	179.6	134.7	107.8	89.8	77.0	67.4	59.9	53.9
0	494.0	247.0	164.7	123.5	98.8	82.3	70.6	61.8	54.9	49.4
5	456.0	228.0	152.0	114.0	91.2	76.0	65.1	57.0	50.7	45.6
0	423.4	211.7	141.1	105.9	84.7	70.6	60.5	52.9	47.1	42.3
5	395.2	197.6	131.7	98.8	79.0	65.9	56.5	49.4	43.9	39.5

Aug 02

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H	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
0	899.7	449.8	299.9	224.9	179.9	150.0	128.5	112.5	100.0	90.0
5	719.7	359.9	239.9	179.9	144.0	120.0	102.8	90.0	80.0	72.0
0	599.8	299.9	199.9	150.0	120.0	100.0	85.7	75.0	66.6	60.0
5	514.1	257.1	171.4	128.5	102.8	85.7	73.4	64.3	57.1	51.4
0	449.8	224.9	150.0	112.5	90.0	75.0	64.3	56.2	50.0	45.0
5	399.8	199.9	133.3	100.0	80.0	66.6	57.1	50.0	44.4	40.0
0	359.9	179.9	120.0	90.0	72.0	60.0	51.4	45.0	40.0	36.0
5	327.1	163.6	109.1	81.8	65.4	54.5	46.7	40.9	36.4	32.7
0	299.9	149.9	100.0	75.0	60.0	50.0	42.8	37.5	33.3	30.0
5	276.8	138.4	92.3	69.2	55.4	46.1	39.5	34.6	30.8	27.7
0	257.0	128.5	85.7	64.3	51.4	42.8	36.7	32.1	28.6	25.7
5	239.9	120.0	80.0	60.0	48.0	40.0	34.3	30.0	26.7	24.0

E 5a1 CATCH AND EFFORT DAT AFOR THE TIMOR SEA/KIMBERLY COAST (123-131E)

,effort(hours),catch(t) as (I4,1X,F6.0,9(1X,F6.1))

ANESE DATA

E(hrs)	catch(t)	nemi	saur	pria	cara	serr	leth	l.lu	s.lu	haem	gold
2017.	871.1	161.8	75.6	11.7	59.3*	3.3*	61.2	108.6*	58.1		
1512.	785.2	168.2	41.6	10.2	29.0*	2.9*	55.1	39.7*	52.4		
8673.	9120.6	954.8	391.9	236.2	1527.6	25.1	597.9	1090.5	467.3		
6664.	5550.3	389.3	295.3	33.6	322.1	26.8	416.1	328.8	456.4		
5911.	4495.6	159.3	327.4	17.7	610.6	327.4	424.8	61.9	17.7		
7063.	6333.3	941.8	444.4	148.1	640.2	63.5	640.2	502.6	492.1		
8324.	7381.3	602.0	371.2	113.7	872.9	50.1	627.1	958.2	431.4		
8357.	2596.8	166.6	176.5	20.9	238.7*	31.8	196.9	522.4*	186.6		
1863.	847.7	120.8	26.2	29.4	86.1	12.4	102.7	117.6	41.6	39.1	30.6
1775.	803.9	94.7	51.4	20.6	90.6	5.7	48.0	119.2	43.5	123.3	39.0
1704.	629.4	25.9	9.2	18.7	28.2	6.8	64.8	164.8	39.8	32.9	148.8
2700.	1337.2	134.5	2.6	28.7	83.4	28.1	155.0	226.1	130.7	147.8	163.5
7028.	3037.8	201.3	122.8	73.7	139.2	34.8	307.2	643.2	194.5	231.2	488.5
6250.	2117.0	192.9	123.9	63.8	63.7	31.0	185.3	408.4	147.3	57.4	361.1
3022.	1003.9	137.9	71.4	39.4	13.2	4.0	101.0	137.9	49.5	45.0	165.8
1464.	527.9	28.2	2.0	7.2	8.8	9.3	42.5	112.9	38.8	8.1	148.8
591.	227.7	40.0	4.3	4.8	12.4	2.9	39.2	27.1	19.0	12.2	29.4
1107.	363.7	12.2	2.8	4.2	3.6	8.8	66.3	143.2	7.0	24.5	47.0
370.	115.2	21.0	.3	3.1	.9	2.4	15.6	27.1	6.6	0.0	12.1

DATA

E(hrs)	catch(t)	nemi	saur	pria	cara	serr	leth	l.lu	s.lu	haem	gold
25.	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
102.	3.9	0.3	0.0	0.0	0.1	0.0	0.3	1.4	0.3	0.5	0.3
390.	33.4	1.1	0.2	0.2	1.5	1.5	2.1	14.5	1.6	7.4	1.2

ESE DATA

E(hrs)	catch(t)	nemi	saur	pria	cara	serr	leth	l.lu	s.lu	haem	gold
2875.	523.9	.5	4.4	1.4	1.1	6.8	66.6	168.3	67.9	58.2	68.1

LE 5a2 CATCH PER UNIT EFFORT ANALYSIS FOR TIMOR SEA

MERCIAL CATEGORY IS SN3 - LARGE LUTJANUS

A FOR TAIWANESE FLEET

YEAR	CATCH	EFFORT	CPUE (KG/HR)
1972	108.	2017.	53.5
1973	39.	1512.	25.8
1974	1090.	8673.	125.7
1975	328.	6664.	49.2
1976	61.	5911.	10.3
1977	502.	7063.	71.1
1978	958.	8324.	115.1
1979	522.	8357.	62.5
1980	117.	1863.	62.8
1981	119.	1775.	67.0
1982	164.	1704.	96.2
1983	226.	2700.	83.7
1984	643.	7028.	91.5
1985	408.	6250.	65.3
1986	137.	3022.	45.3
1987	112.	1464.	76.5
1988	27.	591.	45.7
1989	143.	1107.	129.2
1990	27.	370.	73.0

AVERAGE CATCH=.302E+03 AVERAGE EFFORT=.402E+04

A FOR THAI FLEET

YEAR	CATCH	EFFORT	CPUE (KG/HR)
1986	0.	25.	.0
1987	0.	0.	25.8
1988	1.	102.	9.8
1989	14.	390.	35.9

AVERAGE CATCH=.375E+01 AVERAGE EFFORT=.129E+03

A FOR CHINESE FLEET

YEAR	CATCH	EFFORT	CPUE (KG/HR)
1989	168.	2875.	58.4

AVERAGE CATCH=.168E+03 AVERAGE EFFORT=.288E+04

Table 5a3 (a)

Density of *Lutjanus malabaricus* in the Timor Sea management zone east of 127oE based on data from the 1990 NT survey. The area surveyed was 34900 km2 (n=25).

ESTIMATED DENSITY (kg/km2)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	2729.9	1364.9	910.0	682.5	546.0	455.0	390.0	341.2	303.3	273.0
25	2183.9	1091.9	728.0	546.0	436.8	364.0	312.0	273.0	242.7	218.4
30	1819.9	910.0	606.6	455.0	364.0	303.3	260.0	227.5	202.2	182.0
35	1559.9	780.0	520.0	390.0	312.0	260.0	222.8	195.0	173.3	156.0
40	1364.9	682.5	455.0	341.2	273.0	227.5	195.0	170.6	151.7	136.5
45	1213.3	606.6	404.4	303.3	242.7	202.2	173.3	151.7	134.8	121.3
50	1091.9	546.0	364.0	273.0	218.4	182.0	156.0	136.5	121.3	109.2
55	992.7	496.3	330.9	248.2	198.5	165.4	141.8	124.1	110.3	99.3
60	910.0	455.0	303.3	227.5	182.0	151.7	130.0	113.7	101.1	91.0
65	840.0	420.0	280.0	210.0	168.0	140.0	120.0	105.0	93.3	84.0
70	780.0	390.0	260.0	195.0	156.0	130.0	111.4	97.5	86.7	78.0
75	728.0	364.0	242.7	182.0	145.6	121.3	104.0	91.0	80.9	72.8

STANDARD ERROR (kg/km2)

Width	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	1222.2	611.1	407.4	305.5	244.4	203.7	174.6	152.8	135.8	122.2
25	977.7	488.9	325.9	244.4	195.5	163.0	139.7	122.2	108.6	97.8
30	814.8	407.4	271.6	203.7	163.0	135.8	116.4	101.8	90.5	81.5
35	698.4	349.2	232.8	174.6	139.7	116.4	99.8	87.3	77.6	69.8
40	611.1	305.5	203.7	152.8	122.2	101.8	87.3	76.4	67.9	61.1
45	543.2	271.6	181.1	135.8	108.6	90.5	77.6	67.9	60.4	54.3
50	488.9	244.4	163.0	122.2	97.8	81.5	69.8	61.1	54.3	48.9
55	444.4	222.2	148.1	111.1	88.9	74.1	63.5	55.6	49.4	44.4
60	407.4	203.7	135.8	101.8	81.5	67.9	58.2	50.9	45.3	40.7
65	376.0	188.0	125.3	94.0	75.2	62.7	53.7	47.0	41.8	37.6
70	349.2	174.6	116.4	87.3	69.8	58.2	49.9	43.6	38.8	34.9
75	325.9	163.0	108.6	81.5	65.2	54.3	46.6	40.7	36.2	32.6

Table 5a3(b)

Density of SN3 in the Timor Sea management zone east of 127oE based on data from the 1990 NT survey. The area surveyed was 34900 km2 (n=25).

ESTIMATED DENSITY (kg/km2)

Trawl Width (m)	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	2775.6	1387.8	925.2	693.9	555.1	462.6	396.5	347.0	308.4	277.6
25	2220.5	1110.3	740.2	555.1	444.1	370.1	317.2	277.6	246.7	222.1
30	1850.4	925.2	616.8	462.6	370.1	308.4	264.3	231.3	205.6	185.0
35	1586.1	793.0	528.7	396.5	317.2	264.3	226.6	198.3	176.2	158.6
40	1387.8	693.9	462.6	347.0	277.6	231.3	198.3	173.5	154.2	138.8
45	1233.6	616.8	411.2	308.4	246.7	205.6	176.2	154.2	137.1	123.4
50	1110.3	555.1	370.1	277.6	222.1	185.0	158.6	138.8	123.4	111.0
55	1009.3	504.7	336.4	252.3	201.9	168.2	144.2	126.2	112.1	100.9
60	925.2	462.6	308.4	231.3	185.0	154.2	132.2	115.7	102.8	92.5
65	854.0	427.0	284.7	213.5	170.8	142.3	122.0	106.8	94.9	85.4
70	793.0	396.5	264.3	198.3	158.6	132.2	113.3	99.1	88.1	79.3
75	740.2	370.1	246.7	185.0	148.0	123.4	105.7	92.5	82.2	74.0

STANDARD ERROR (kg/km2)

Width	Trawl Retention .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
20	1222.5	611.3	407.5	305.6	244.5	203.8	174.6	152.8	135.8	122.3
25	978.0	489.0	326.0	244.5	195.6	163.0	139.7	122.3	108.7	97.8
30	815.0	407.5	271.7	203.8	163.0	135.8	116.4	101.9	90.6	81.5
35	698.6	349.3	232.9	174.6	139.7	116.4	99.8	87.3	77.6	69.9
40	611.3	305.6	203.8	152.8	122.3	101.9	87.3	76.4	67.9	61.1
45	543.3	271.7	181.1	135.8	108.7	90.6	77.6	67.9	60.4	54.3
50	489.0	244.5	163.0	122.3	97.8	81.5	69.9	61.1	54.3	48.9
55	444.5	222.3	148.2	111.1	88.9	74.1	63.5	55.6	49.4	44.5
60	407.5	203.8	135.8	101.9	81.5	67.9	58.2	50.9	45.3	40.8
65	376.2	188.1	125.4	94.0	75.2	62.7	53.7	47.0	41.8	37.6
70	349.3	174.6	116.4	87.3	69.9	58.2	49.9	43.7	38.8	34.9
75	326.0	163.0	108.7	81.5	65.2	54.3	46.6	40.8	36.2	32.6

E 6a1 CATCH AND EFFORT DATA FOR THE NORTH WEST SHELF (115-123E)

effort(hours),catch(t) as (I4,1X,F6.0,10(1X,F6.1))

ANESE DATA

E(hrs)	catch(t)	nemi	saur	pria	cara	serr	leth	l.lu	s.lu	haem
500.	273.0	39.2	16.1	11.7	33.5*	2.7*	29.9	20.6*	12.9	
64545.	37143.0	8377.3	2711.4	69.9	865.5*	374.4*	4076.4	2181.7*	1762.4	
79860.	31256.3	7934.7	4276.4	618.1	1462.3	226.1	2653.3	1487.4	1281.4	
57767.	21288.6	5033.5	3355.7	369.1	684.5	275.2	2865.7	1107.4	1147.6	
46592.	18929.2	4530.9	3061.9	327.4	1168.1	168.1	1840.7	336.3	469.0	
56413.	19080.0	4517.9	3199.4	318.4	1059.5	193.4	2000.0	556.5	776.8	
40998.	14488.3	3431.5	1951.9	392.1	889.2	120.9	1701.2	596.2	755.1	
33500.	10764.0	2168.5	1937.2	208.6	594.8*	156.2	753.6	296.7	411.0	
36806.	13805.8	4133.7	942.0	327.0	897.0	278.8	1929.9	693.6	583.5	241.7
30962.	12335.0	4599.2	797.5	346.8	808.6	109.8	1347.6	454.3	620.1	114.4
39385.	14886.0	4352.2	581.5	329.3	929.7	306.2	2109.9	786.0	1005.5	163.9
30192.	10992.1	4108.8	413.5	171.0	513.7	280.4	1314.7	403.9	770.3	151.6
38934.	11642.5	4276.5	613.0	187.3	537.5	238.7	1082.1	455.8	919.7	148.0
38401.	11075.1	3504.9	697.8	236.0	633.8	235.4	1129.6	611.8	827.6	126.4
12311.	3134.2	1097.6	349.7	62.7	172.9	39.9	294.1	125.8	178.2	23.8
5011.	1682.9	490.0	166.5	64.9	75.1	89.1	237.1	63.8	118.0	15.1
7385.	2254.4	692.3	331.7	51.8	67.8	82.9	188.7	133.1	198.3	10.3
10470.	2833.5	572.6	112.8	58.8	48.2	114.4	520.0	322.0	240.8	148.2
681.	208.3	45.8	2.6	6.1	.8	17.0	20.8	23.4	25.8	0.0

SE DATA

E(hrs)	catch(t)	nemi	saur	pria	cara	serr	leth	l.lu	s.lu	haem
3185.	863.5	13.9	3.8	3.1	9.1	8.2	491.6	83.6	8.1	70.1

STIC TRAWL DATA

E(hrs)	catch(t)	nemi	perch	argy	cara	serr	leth	l.lu	s.lu	haem
3846.	106.5	2.5	3.5	2.2	6.3	18.5	10.7	41.6		4.0
11910.	392.3	18.6	11.9	22.0	21.5	34.0	80.1	133.0		9.9

BLE 6A2 COMBINED CATCH AND STANDARDISED EFFORT DATA FOR THE NORTH WEST SHELF

ET1 = TAIWANESE
ET2 = CHINESE
ET3 = DOMESTIC

MERCIAL CATEGORY SN3 - LARGE LUTJANIDS

YEAR	TOTAL CATCH	STD EFFORT	CPUE	RATIO2	RATIO3	RETAIN
1972	20.	500.	.0400	.000	.000	1.00
1973	2181.	64545.	.0338	.000	.000	1.00
1974	1487.	79860.	.0186	.000	.000	1.00
1975	1107.	57767.	.0192	.000	.000	1.00
1976	336.	46592.	.0072	.000	.000	1.00
1977	556.	56413.	.0099	.000	.000	1.00
1978	596.	40998.	.0145	.000	.000	1.00
1979	296.	33500.	.0088	.000	.000	1.00
1980	693.	36806.	.0188	.000	.000	1.00
1981	454.	30962.	.0147	.000	.000	1.00
1982	786.	39385.	.0200	.000	.000	1.00
1983	403.	30192.	.0133	.000	.000	1.00
1984	455.	38934.	.0117	.000	.000	1.00
1985	611.	38401.	.0159	.000	.000	1.00
1986	125.	12311.	.0102	.000	.000	1.00
1987	63.	5011.	.0126	.000	.000	1.00
1988	133.	7385.	.0180	.000	.000	1.00
1989	446.	14502.	.0308	.847	.347	1.00
1990	156.	4619.	.0338	.000	.331	1.00

AVERAGE CATCH=.574E+03 AVERAGE EFFORT=.336E+05

WHERE STD EFFORT = SUM(EFFORT*RATIOX) ACROSS FLEETS WHERE
RATIOX IS COMPARISON OF CPUE OF FLEETX WITH FLEET 1

E 6b1 RESULTS OF SURPLUS PRODUCTION ANALYSIS FOR NORTH WEST SHELF

COMMERCIAL CATEGORY SN3 - LARGE LUTJANUS

MASS CALCULATED USING THE LOGISTIC SURPLUS PRODUCTION MODEL
T+1)=B(T)*(1+R-R*B(T)/K-Q*E(T))
C(T)=Q*E(T)*B(T)*D
RE D=PROPORTION OF CATCH RETAINED

PORTION OF CATCH RETAINED HAS FORM
(T)=Do*(1+AA*T) T=YEARS SINCE START OF FISHING
RE Do=1.00 AA= .00

CHABILITY COEFFICIENT ASSUMED CONSTANT FOR ALL YEARS

YEAR	TOTAL CATCH	STD EFFORT	CPUE
1972	20.	500.	.0400
1973	2181.	64545.	.0338
1974	1487.	79860.	.0186
1975	1107.	57767.	.0192
1976	336.	46592.	.0072
1977	556.	56413.	.0099
1978	596.	40998.	.0145
1979	296.	33500.	.0088
1980	693.	36806.	.0188
1981	454.	30962.	.0147
1982	786.	39385.	.0200
1983	403.	30192.	.0133
1984	455.	38934.	.0117
1985	611.	38401.	.0159
1986	125.	12311.	.0102
1987	63.	5011.	.0126
1988	133.	7385.	.0180
1989	446.	14502.	.0308
1990	156.	4619.	.0338

VERAGE CATCH=.574E+03 AVERAGE EFFORT=.336E+05

HERE STD EFFORT = SUM(EFFORT*RATIOX) ACROSS FLEETS WHERE
RATIOX IS COMPARISON OF CPUE OF FLEET X WITH FLEET 1

RID SEARCH TO MINIMIZE THE LIKELIHOOD FUNCTION
SUM(LOG(C(T)/PREDC))**2
TO BE CARRIED OUT ACROSS THE FOLLOWING VALUES

Q	R	K
.100E-05	.100E-01	.800E+03
.300E-05	.150E+00	.230E+04
.500E-05	.300E+00	.380E+04
.700E-05	.450E+00	.533E+04
.900E-05	.600E+00	.680E+04
.110E-04	.750E+00	.830E+04
.130E-04	.900E+00	.980E+04

IMUM OF LIKELIHOOD FUNCTION = 1.4344 WHERE

000E+00 S=.000E+00 Q=.700E-05 R=.450E+00 K=.533E+04

95% CONFIDENCE REGION ON THE LIKELIHOOD SURFACE IS GIVEN BY VALVES
LOG(LIKELIHOOD) < 4.56

CENTAGE OF POINTS WITHIN CRITICAL REGION= 15.5

0 % OF BOUNDARY OF A IN THE CRITICAL REGION
0 % OF BOUNDARY OF S IN THE CRITICAL REGION
0 % OF BOUNDARY OF Q IN THE CRITICAL REGION
2 % OF BOUNDARY OF R IN THE CRITICAL REGION
1 % OF BOUNDARY OF K IN THE CRITICAL REGION

ICTED BIOMASS AND CATCHES USING ABOVE EFFORT AND THE
LUS PRODUCTION MODEL WITH THE FOLLOWING PARAMETERS

YEAR	BIOMASS	CATCH	PRED CATCH	SKILL
1972	5330.	20.	19.	1.00
1973	5311.	2181.	2400.	1.00
1974	2920.	1487.	1632.	1.00
1975	1882.	1107.	761.	1.00
1976	1669.	336.	544.	1.00
1977	1640.	556.	648.	1.00
1978	1504.	596.	431.	1.00
1979	1558.	296.	365.	1.00
1980	1689.	693.	435.	1.00
1981	1773.	454.	384.	1.00
1982	1921.	786.	530.	1.00
1983	1944.	403.	411.	1.00
1984	2089.	455.	569.	1.00
1985	2091.	611.	562.	1.00
1986	2101.	125.	181.	1.00
1987	2493.	63.	87.	1.00
1988	3002.	133.	155.	1.00
1989	3437.	446.	349.	1.00
1990	3638.	156.	118.	1.00

CH VS. YEAR   * =CATCH TAKEN   + =PREDICTED CATCH

```
        500.     1000.     1500.     2000.     2500.     3000.     3500.     4000.
  ---------|---------|---------|---------|---------|---------|---------|---------|
2 |
3 |                                           *   +
4 |                             *  +
5 |              +      *
6 |      *   +
7 |          * +
8 |        +  *
9 |     *+
0 |        +    *
1 |       +*
2 |          +    *
3 |       E
4 |        * +
5 |          +*
6 |  *+
7 |*+
8 |  E
9 |      + *
0 | +*
```

MUM SUSTAINABLE YIELD=   600. TONNES
RT AT MSY=   32143. HOURS WITH 1990 Q
RT AT MSY=   32143. HOURS WITH 1991 Q
CTED BIOMASS AT START OF 1991, B= 4040. TONNES
ICTED CATCH COEFFICIENT FOR 1991, Q= .700E-05
ICTED FISHING MORTALITY FOR 1991, F= .225

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CULATION OF MSY AND EMSY DISTRIBUTIONS

IANCE OF NORMAL ERROR= .1225


NG VALUES FOUND WITHIN CRITICAL REGION WEIGHTED BY LIKELIHOOD
N MSY=       606.   STD DEVIATION=       64.

QUENCY OF VALUES
                                20        40        60        80       100
OM    TO       %   ---------|---------|---------|---------|---------|
311.-   437.   9. *****
436.-   561.   9. *****
560.-   686.  19. *********
685.-   810.  30. ***************
809.-   935.   8. ****
934.-  1059.  11. ******
058.-  1184.   2. *
183.-  1308.   8. ****
307.-  1433.   0.
432.-  1557.   2. *


TRIBUTION OF LIKELIHOOD
                                .2        .4        .6        .8       1.0
OM    TO       %   ---------|---------|---------|---------|---------|
311.-   437.   0.
436.-   561.   9. *****
560.-   686.  80. ****************************************
685.-   810.  10. *****
809.-   935.   0.
934.-  1059.   0.
058.-  1184.   0.
183.-  1308.   0.
307.-  1433.   0.
432.-  1557.   0.


NG VALUES FOUND WITHIN CRITICAL REGION WEIGHTED BY LIKELIHOOD
MASS AT START OF 1991=     4142.   STD DEVIATION=      590.

QUENCY OF VALUES
                                20        40        60        80       100
OM    TO       %   ---------|---------|---------|---------|---------|
109.-  2809.   6. ***
808.-  3508.  19. *********
507.-  4207.  19. *********
206.-  4906.  11. ******
905.-  5604.  21. **********
603.-  6303.   6. ***
302.-  7002.   9. *****
001.-  7701.   0.
700.-  8400.   8. ****
399.-  9098.   0.


TRIBUTION OF LIKELIHOOD
                                .2        .4        .6        .8       1.0
OM    TO       %   ---------|---------|---------|---------|---------|
109.-  2809.   0.
808.-  3508.  13. *******
507.-  4207.  58. *****************************
206.-  4906.  22. ***********
905.-  5604.   4. **
603.-  6303.   0.
302.-  7002.   2. *
001.-  7701.   0.
700.-  8400.   0.
399.-  9098.   0.
```

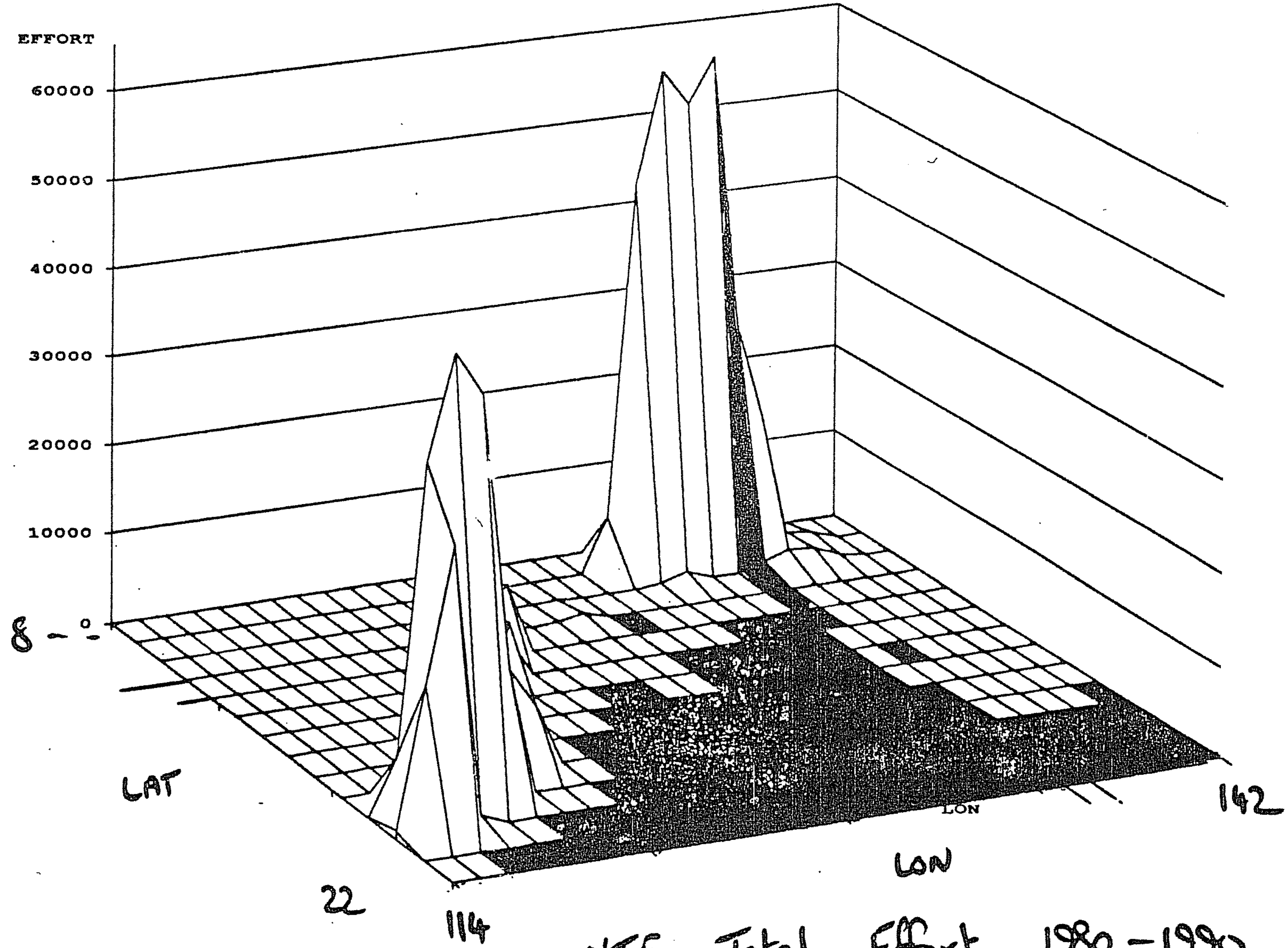

FIGURE 7h1.

'WESSEL' BUFFER

NTF Total Effort 1980-1990

Table 7b.1

Distribution of total retained catch(t) for SN3 in the Arafura Sea fishery during 1980-90. The proposed Wessel Buffer Zone would close the fishery in the region 136-137oE. Data were pooled across all foreign and domestic fleets. The total catch of SN3 durng 1980-90 was approximately 22330t.

Lat S \ Longitude E	131–132	132–133	133–134	134–135	135–136	136–137	137–138	138–139	139–140	140–141	141–142
9–10			5	255	573	2899	232	3	6		
10–11	1	390	2639	3920	3557	4407	1876	1040	97	48	1
11–12			4	25	1	1	80	119	95	55	
12–13						1					
All latitudes Catch	1	390	2648	4200	4131	7308	2188	1162	198	103	1
% Catch	0	2	12	19	18	33	10	5	1	1	0