# Quantification of changes in recreational catch and effort on inner Shark Bay snapper species following implementation of responsive management changes

*N.R. Sumner and B.E. Malseed*


Department of
Fisheries

FISHERIES
RESEARCH &
DEVELOPMENT
CORPORATION

*Fish for the future*

## Project No. 2000/139

July 2002

ISBN 1 877098 05 1

# Table of Contents

**2000/139 Quantification of changes in recreational catch and effort on inner Shark Bay snapper species following implementation of responsive management changes**

**PRINCIPAL INVESTIGATOR:** Mr Neil Sumner

**ADDRESS:** Department of Fisheries Western Australia
Research Division
PO Box 20
North Beach W.A. 6920
Telephone: 08 9246 8438 Fax: 08 9447 3062

# OBJECTIVES

1. To estimate the proportion of pink snapper stock harvested by recreational fishers using results from this creel and daily egg production method surveys.

2. To provide an estimate of the recreational catch of all species including fish (esp. pink snapper and grass emperor), sharks, crustaceans and molluscs in the Shark Bay region.

3. To provide an estimate of the recreational fishing effort in the Shark Bay region.

4. To assess changes in fishing effort after the introduction of new management regulations.

5. To provide information on length frequency of the recreational catch for pink snapper, grass emperor and other key recreational species.

# NON TECHNICAL SUMMARY

**OUTCOMES ACHIEVED**

The estimated recreational catch of pink snapper landed at Nanga and Tamala Station was 22 tonnes with between 40% and 100% of the spawning stock harvested from the Freycinet Estuary. The spawning biomass was estimated after most of the catch had been taken. This situation is critical and new management measures have been put in place. Monitoring of the catch and fishing effort by the Department of Fisheries WA is continuing.

The estimated catch of pink snapper landed at Denham was eight tonnes with 11% or less of the spawning stock from Freycinet Reach harvested. Present catch levels from Freycinet Reach are considered to be sustainable, however, monitoring of the catch and fishing effort by the Department of Fisheries WA is continuing.

The total recreational boat-based catch of all finfish species in Shark Bay was estimated at 50 tonnes. The most common species kept by recreational fishers in Shark Bay were (in order of weight kept) pink snapper (30 tonnes), grass emperor (7 tonnes), mulloway (3 tonnes), estuary cod (2 tonnes), tailor (1 tonne), Queensland school mackerel (1 tonne) and whiting species (1 tonne).

The estimated total recreational boat-based fishing effort in Shark Bay for the 12-month period was 34,000 fisher days, comprising 31,000 fisher days by boats launched from public ramps and 3,000 fisher days for boats launched from the beach at Tamala Station.

Changes to the recreational catch and fishing effort following the introduction of new management measures were assessed. The new management measures were not effective in reducing the recreational catch to target levels. This study has highlighted the limitations of traditional management measures such as size and bag limits. For this reason, two new management methods to limit the recreational catch of pink snapper, 1) issuing a limited number of tags required for fish kept; and 2) closing the fishery once the catch allocation has been achieved, are now being implemented for the inner gulf pink snapper stocks within Shark Bay.

The length frequency for pink snapper was reported for Freycinet Reach (Denham) and Freycinet Estuary (Nanga). The length frequency for grass emperor was reported for the western gulf (Denham and Nanga) and eastern gulf (Monkey Mia) of Shark Bay. Length information for other species was also recorded at the boat ramp by the survey interviewers.

A 12-month creel survey of recreational boat-based fishing in Shark Bay, Western Australia was conducted between May 2001 and April 2002 to estimate the catch of pink snapper. During the survey 431 boat crews were interviewed at public boat ramps of which 414 had been fishing.

The information was required to assess the sustainability of pink snapper stocks at present levels of recreational fishing and to determine the most appropriate management measures required to keep recreational catches within management targets.

Pink snapper were predominantly caught from Freycinet Estuary and landed at Nanga (17.5 tonnes) or Tamala Station (4.7 tonnes). Pink snapper caught from Freycinet Reach were landed at Denham (7.5 tonnes). Catches from these stocks have decreased from 25.7 tonnes landed at Nanga and 12.2 tonnes landed at Denham estimated by a survey conducted in 1998-99 (Sumner *et al.*, 2002).

The impact of revised management measures introduced in the western gulf to reduce the recreational catch of pink snapper was predicted using catch and effort data collected from surveys completed prior to their introduction. The revised management measures included a minimum size limit of 500 mm, bag limit of two, a limit of one fish over 700 mm per person and a partial closure to fishing for pink snapper in Freycinet Estuary (south of Goulet Bluff) between 15 August and 30 September during the spawning period. The predictions were found to be accurate when compared to catches estimated from a creel survey following the introduction of new regulations.

As predicted, despite the introduction of the new management measures, the estimated catch of pink snapper in Freycinet Estuary was four times the management target catch of five tonnes. In Freycinet Reach, the new management measures reduced the landed catch by one quarter with a corresponding increase in the number of undersize fish released. The effectiveness of the revised management measures varied between Freycinet Estuary and Freycinet Reach due to the different size composition of the recreational catch of pink snapper at these locations.

The limited effectiveness of the recently introduced management measures indicates that small and vulnerable stocks, such as the inner gulf pink snapper stocks in Shark Bay, cannot be effectively managed using standard techniques such as size and bag limits. Traditional recreational management methods based on size and bag limits did not reduce the catch in Freycinet Estuary to a sustainable level. Furthermore, due to the minimum size limit, large numbers of pink snapper are being caught and subsequently released particularly in the Freycinet Reach. Consequently, the mortality of fish caught and subsequently released is of concern (This is the focus of another project FRDC 2000/194 "Investigating survival of released undersized west coast reef fish"). These problems will provide challenges for the management of this and other similar recreational fisheries.

**KEYWORDS: Recreational Fishing, Pink Snapper, Shark Bay, Creel Survey**

# 1.0 Background

*Recreational fishing in Shark Bay*

Recreational fishing in the Shark Bay World Heritage Property (Figure 1) is one of the primary reasons people visit the area, and line fishing is the most popular water-based activity, with an annual participation of 89,000 fisher days (Sumner *et al*., 2002). Recreational boat and shore fishers target a range of demersal and pelagic fish species within the Shark Bay World Heritage Property. However, the recreational catch is dominated by two species, pink snapper (*Pagrus auratus)* and grass emperor (known locally as black snapper or blue-lined emperor) (*Lethrinus laticaudis*).

*Past research*

Past studies by the Department of Fisheries, Western Australia have identified that pink snapper is the prime species caught by recreational fishers in the Shark Bay World Heritage Property (Sumner and Steckis, 1999; Sumner and Malseed, 2001). A more recent survey (Sumner *et al.*, 2002) indicated that exploitation rates had increased since an earlier Department of Fisheries survey in 1983 (Moran, pers. comm.).

Three distinct genetic stocks of pink snapper have been identified in Shark Bay; the eastern gulf stock; western gulf stock and oceanic stock (Johnson *et al*., 1986; Moran, 1987; Edmonds et al., 1989). More recent studies indicate the existence of two separate stocks in the western gulf, Freycinet Reach/Denham Sound and Freycinet Estuary, which are managed accordingly (Jackson and Stephenson, 2002). The spawning biomass of pink snapper stocks in both the eastern and western gulfs of Shark Bay has been estimated since 1997 (Jackson and Stephenson, 2002). Monitoring the size of these isolated stocks using the daily egg production method was planned to continue until the eastern gulf recovers from a severely reduced breeding stock due to several years of intensive recreational fishing. The eastern gulf was closed to the taking of pink snapper on June 9, 1998.

There is now concern for pink snapper stocks in the western gulf due to increasing fishing effort within Shark Bay over the past decade. Pressure on the pink snapper stock in the western gulf increased during the 90's with 38 tons of pink snapper landed by recreational fishers during 1998 (Sumner *et al*., 2002). The level of catch from Freycinet Estuary (Nanga) (26 tonnes) was of particular concern. For this reason new management measures were introduced to reduce the catch from the Freycinet Estuary to a management target of five tonnes. Therefore, a present estimate of the recreational catch for the western gulf and the proportion of the biomass harvested by recreational fishers over a 12-month period was required.

Recreational anglers were targeting and catching large quantities of grass emperor. There were also management and community concerns about the intensive recreational fishing pressure on this species.

*The National Recreational Fishing Survey (FRDC 1999/158)*

A national phone/diary survey of recreational fishing was conducted from May 2000 – April 2001. This survey was designed to provide general estimates of catch and fishing effort for large regions of the state including the Gascoyne bioregion. Information collected by the

National Recreational Fishing Survey includes 183 fishing events in Shark Bay from 43 households. However, from these preliminary results it is clear that the National Survey cannot be used to estimate the recreational catch and fishing effort for individual pink snapper stocks within Shark Bay. This project to estimate the recreational catch for Shark Bay has been designed at the scale necessary to deal with stock specific impacts in the inner gulfs.

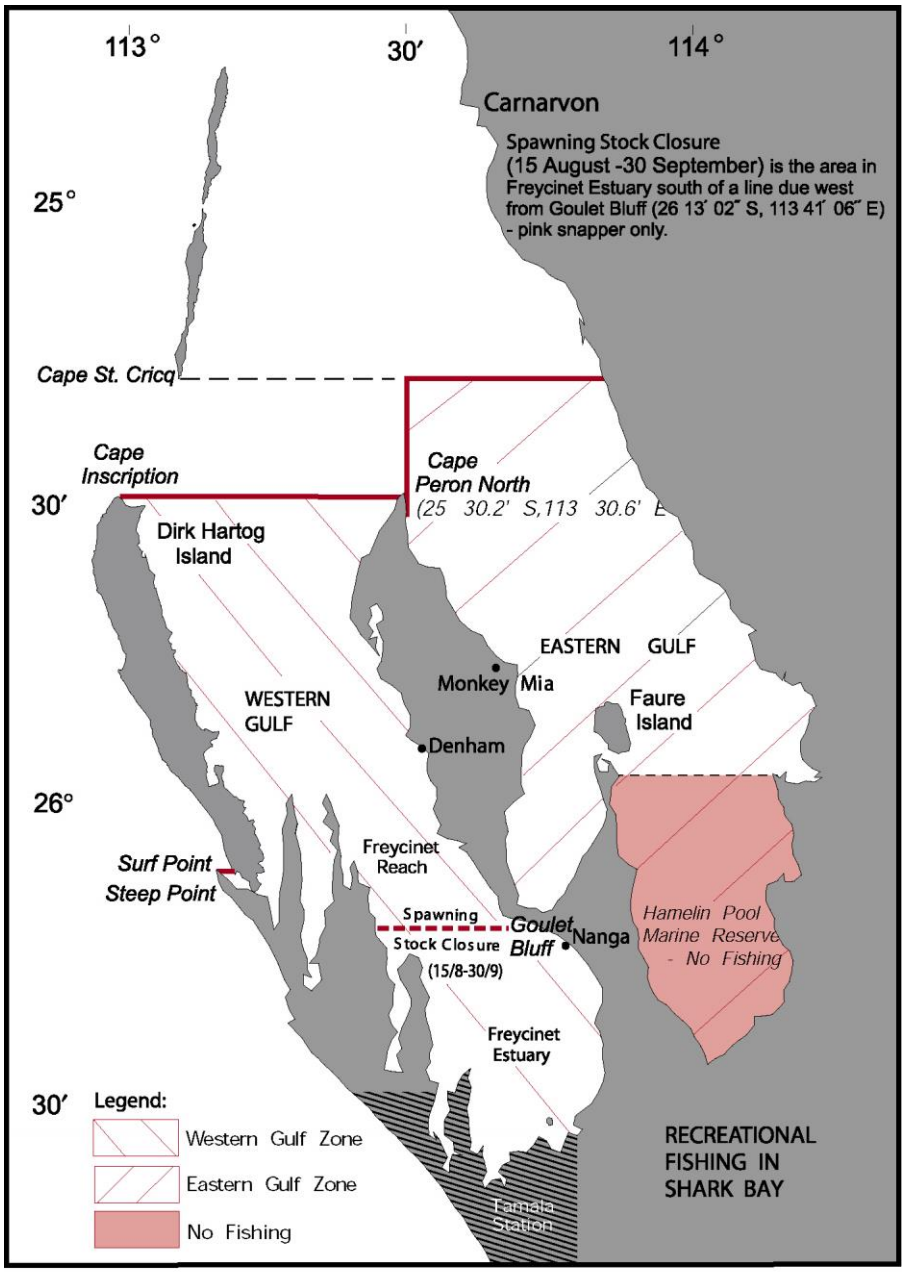



**Figure 1** Shark Bay showing boat ramps surveyed

# 2.0 Need

The size of the recreational catch of pink snapper together with information on the stock size from the daily egg production method (separate study funded by the Department of Fisheries) was required to estimate the proportion of the stock taken by recreational fishers over a one year period. This information will be used to assess the sustainability of present levels of recreational fishing and to determine the most appropriate management measures required to keep recreational catches within management targets.

The Gascoyne Region Working Group has noted that a major obstacle to the resolution of fishery management and resource sharing issues in the region was the scarcity of data on recreational catches and fishing activity. Additional monitoring beyond previous creel surveys, funded by the Department of Fisheries in 1998/99, and World Heritage Trust in 2000/01, was required to estimate changes to the total catch, catch rates, and size composition of pink snapper and other key species.

An estimate of the recreational catch, fishing effort, catch rates and fishing location for grass emperor was required for the related FRDC project "The age, growth, reproductive biology and stock assessment of grass emperor, *Lethrinus laticaudis* in Shark Bay, WA" (FRDC 1999/152).

# 3.0 Objectives

The objectives of the project were to estimate the annual harvest of pink snapper made by recreational fishers from the inner gulfs of Shark Bay, Western Australia. Specifically, the objectives were:

**1.** To estimate the proportion of pink snapper stock harvested by recreational fishers using results from this creel and daily egg production method surveys.

2. To provide an estimate of the recreational catch of all species including fish (esp. pink snapper and grass emperor), sharks, crustaceans and molluscs in the Shark Bay region.

3. To provide an estimate of the recreational fishing effort in the Shark Bay region.

4. To assess changes in fishing effort after the introduction of new management regulations.

5. To provide information on length frequency of the recreational catch for pink snapper, grass emperor and other key recreational species.

# 4.0 Methods

Information on the boat-based recreational catch and fishing effort was obtained from creel surveys.

## 4.1 Survey design

Two creel survey methods were used to estimate the recreational catch of all species for boat-based fishers in Shark Bay. The bus route method (Robson and Jones 1989, Jones *et al*. 1990), where a survey interviewer visits all boat ramps in a district on the one day, was used for trailered boats launched from public boat ramps. A roving creel survey was used to estimate the catch and fishing effort for fishers launching small boats from beaches at Tamala Station.

Catch and fishing effort information for recreational fishers was recorded at a resolution of 5×5 nautical miles. These blocks fit within the statistical blocks used for recording the commercial catch in Western Australia (60×60 nautical mile) and offer a finer resolution preferred for reporting the recreational catch.

The catch and fishing effort from charter boats was not included in the study since a compulsory returns system for tour operators was in place at the time. Returns received from Tour Operators show that they generally target the oceanic stock rather than inner gulf pink snapper stocks within Shark Bay and hence the reported catch from the inner gulfs during the survey period was negligible.

## 4.2 Spatial and temporal stratification

The 12-month survey commenced in May 2001 and concluded at the end of April 2002.

The survey of public boat ramps was stratified by district, season (spring, summer, autumn or winter) and school holiday periods (April, July and October). Separate total catch and fishing effort estimates were made for each of the 7 strata (4 seasons + 3 for school holidays). These estimates were then aggregated to obtain the total recreational boat-based catch and effort for Shark Bay.

The roving creel survey of fishers launching boats from beaches at Tamala Station was only conducted between May 2001 and October 2001. This survey was not stratified due to the limited fishing season at this location.

## 4.3 Sampling design

*Boats launched at public boat ramps – bus route method*

A bus route was set up for the three public boat ramps in Shark Bay – Nanga, Denham and Monkey Mia (Figure 1). Relatively more days were allocated to the season where most fishing effort occurred, based on prior information on recreational fishing patterns provided by

previous creel surveys conducted in Shark Bay (Sumner *et al*., 2002; Sumner and Malseed, 2001). This resulted in between four and twelve survey days being allocated per month.

The bus route schedules were constructed as described by Pollock *et al*. (1994). The start, travel and wait times for each ramp were rounded to the nearest minute. A Mathcad (Anonymous, 1999) worksheet was developed to generate the randomised schedules.

The starting boat ramp and direction of travel for the bus route was chosen randomly. The bus route commenced either between ramps or at a ramp. However, due to the large distances between boat ramps, travel time and cost involved, starting at a ramp and returning to the same ramp to complete the route at the end of the shift was inefficient. Furthermore, removing this last leg of the bus route allowed more time to be spent at the boat ramps collecting data rather than travelling. For this reason, the bus route method was constrained so that a shift could not commence part way through the wait time at a ramp although the probability of commencing at a ramp or travelling remained unchanged. It was likely that each boat ramp was visited during all hours of the day by the end of a season. McGlennon and Kinloch (1997) used a similar modification of the bus route method for a survey conducted in South Australia where boat ramps were separated by large distances.

The initial allocation of wait time to each ramp was based on prior information of ramp usage. The wait time allocated was proportional to the previously recorded recreational fishing effort at each ramp. This was reviewed as data from the survey became available. The route was chosen to minimise the distance travelled between boat ramps.

Within each stratum a random sample of survey days was chosen. When it was not possible for recreational boats to fish due to severe weather conditions, the survey was not conducted and it was assumed that there was zero catch and fishing effort for the day. The survey interviewer made this decision on the day after assessing the weather conditions. It was assumed that the number of survey days where recreational fishing was not possible due to severe weather was representative of each season.

The survey of boat ramps was restricted to seven hours during the day, from 11:00 am to 6:00 pm, which included predominant fishing activity. Periods of lower fishing activity, such as at night, could not be covered with the available resources. Prior information suggested that, although night fishing occurred at certain times of the year, it comprised only a small portion of the total recreational fishing effort. Almost all recreational boats return to the boat ramps by 6:00 pm to avoid having to navigate the return trip in darkness. The safety of interviewers at night was also a concern.

The interviewer followed a pre-determined schedule specifying the boat ramps to visit and the sampling time for each boat ramp. Catch, fishing effort, biological, attitudinal and demographic information were collected from boat-based fishers. A form was used to record the environmental conditions as well as the time of boat launches and retrievals while the interviewer was at a boat ramp (Appendix 3). Only recreational boat trailers were counted at the boat ramps; these could be distinguished from trailers used by professional fishers. A second form was used to record the time-spent fishing, catch, and other information for individual boats (Appendix 4). The catch was recorded at the completion of the day's fishing and represents the entire catch for the duration of the trip. The landed catch of each species was counted and measured.

*Tamala Station – roving creel survey*

A roving creel survey was used for boat-based fishers that launched small boats from beaches at Tamala Station. These locations were only accessible by four-wheel drive vehicle. Instantaneous counts of the number of boats fishing, estimated by counting boat trailers and vehicles with roof racks, were made on arrival at each fishing location visited. The time spent fishing, catch and other relevant information was recorded when boat crews returned from the fishing trip (Appendix 5). At camping sites, groups of people were interviewed to collect participation and catch rate information.

As with the bus route method, the duration of the patrols were limited to daylight hours due to concerns for the safety of staff and budgetary constraints. Night fishing activities, although considered to be minor, were not included.

### 4.4 Estimation of total catch and effort

*Boats launched at public boat ramps – bus route method*

The fishing effort for the day was estimated from counts of the number of trailers at the boat ramps. Catch rates were estimated from information on the time spent fishing and catch obtained by interviewing fishers when they returned to the boat ramp at the completion of the fishing trip. The total catch was estimated by multiplying the catch rate by the estimate of fishing effort in fisher hours (Appendix 6).

The measure of fishing effort for each season was adjusted to correct for the number of boats not involved in fishing activities. The correction was made by multiplying trailer counts by the proportion of boats interviewed that were participating in recreational fishing.

Fishing effort by boats that were launched before the start of a morning shift (11.00am) and returned after the start of the morning shift was also taken into account. The ratio of effort occurring prior to the start of a morning shift to that occurring after the start of a morning shift was estimated and a correction factor (*f*) applied to the effort estimate in the mornings for each season (Appendix 6).

The total number of fish both kept and released for all species was estimated. The standard error associated with the estimate of the number of fish kept $SE(\hat{c})$ was calculated for each species. Assuming a student *t* distribution, the (1-α) percent confidence interval for the number kept $(\hat{c})$ was calculated from the standard error as follows:

$$\hat{c} \pm t(1-\alpha/2; n-1)SE(\hat{c})$$
$$\hat{c} \pm 1.96\ SE(\hat{c})$$

where $\alpha = 0.05$ for the 95% confidence interval and *n* is the number of boats surveyed (sample size). The estimates reported in the results (Section 5.0) have been rounded to reflect the level of precision.

*Tamala Station – roving creel survey*

The boat-hours of fishing effort for the day were calculated by multiplying the instantaneous counts by the number of hours in the fishing day. Catch rates were estimated from

information on the time spent fishing and catch obtained by interviewing boat-based fishers when they returned to the beach at the completion of the fishing trip. The total catch was estimated by multiplying the catch rate by the estimate of fishing effort in fisher hours (Appendix 7).

*Weight estimation*

The whole weight of the catch, in tonnes, was estimated from the number kept, size composition and the length to weight relationships calculated for each species. The weight of fish kept has been reported for the predominant species.

### 4.5 Evaluation of new management measures

The impact of revised management measures to be introduced in the western gulf on the recreational catch of pink snapper was predicted using catch and effort data collected prior to their introduction. The predictions were based on the proportion of the previous catch that would comply with the revised regulations assuming that the abundance, size composition and catchability of fish and efficiency of anglers did not change following the introduction of revised regulations and that anglers comply with the regulations.

The annual catch for 2000 was predicted from creel survey data collected in 1998-99 allowing for the introduction of a partial seasonal closure from August 15 to September 30 in the Freycinet Estuary. For 2001, the annual catch was predicted allowing for changes in bag and size limits assuming fishing effort remained the same after the introduction of the new regulations. The accuracy of these predictions were evaluated by comparing the predicted catches with catch estimates from the creel surveys conducted following the introduction of new regulations.

When two or more new management measures are introduced at the same time, the effects of the individual management changes must be combined to estimate the overall effect. The correct method to calculate the combined effect depends upon whether or not the new management measures are independent of each other. For example, the effect of a new minimum size limit is likely to be independent of the effect of a closure. However, the effect of a new minimum size limit is not likely to be independent of the effect of a reduction in the bag limit because the new minimum size limit is likely to make any bag limit more difficult to achieve.

For management measures that are independent the following formula applies:

$$P(A \text{ and } B) = P(A) \times P(B)$$

where P(A) is the proportion of the original catch expected after the introduction of the first management measure and P(B) is the proportion of the original catch expected after the introduction of the second management measure. However, if the management measures are not independent the following formula applies:

$$P(A \text{ and } B) = P(A) \times P(B \mid A)$$

Where P(B | A) is the conditional probability of an event B given another event A. In the above example P(B | A) is the additional impact of a reduction in bag limit following a

increase in size limit P(A). When the two measures are not independent, the combined impact will be less effective since the management measures will tend to counteract each other and reduce the overall impact.

# 5.0 Results/discussion

During the survey 431 boat crews were interviewed at public boat ramps after they had returned from their trip. Of these, 407 boat crews had been angling and eight had used drop nets to catch blue swimmer crabs (of which one was both angling and crabbing). The remaining 17 boat crews had not participated in fishing activities. No boat crews interviewed had been diving using compressed air or snorkelling. A further 116 groups were interviewed at Tamala station. Of these, 97 had been fishing either earlier that day or the day before (of which 87 were fishing from boats and 10 from the shore).

The greater proportion of recreational fishers interviewed in the region were from the Perth metropolitan area (Figure 2). However, there were also a large proportion of residents from elsewhere in the state.

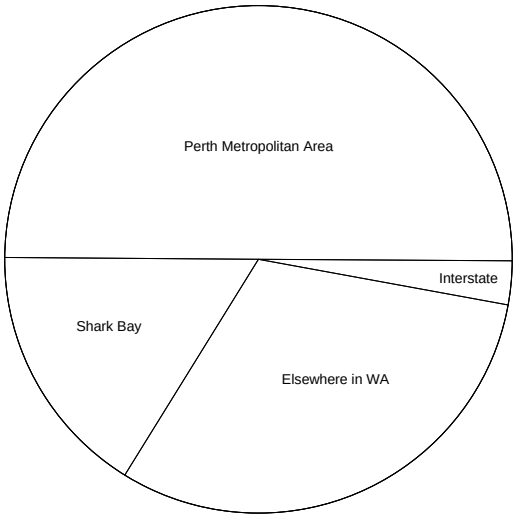
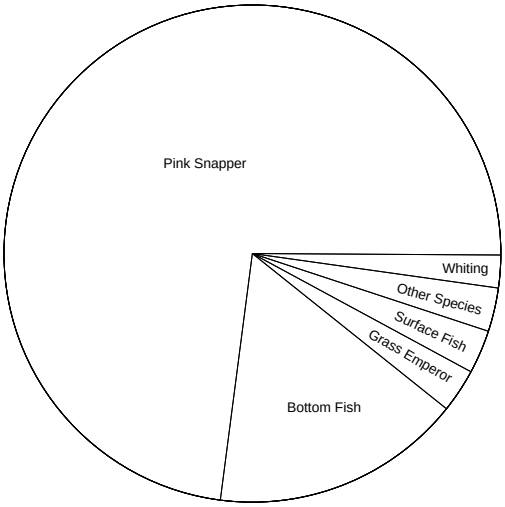


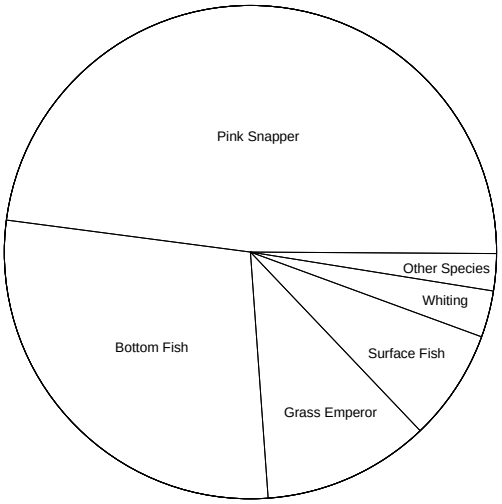

**Figure 2** Place of residence of recreational fishers in Shark Bay

## 5.1 Species targeted

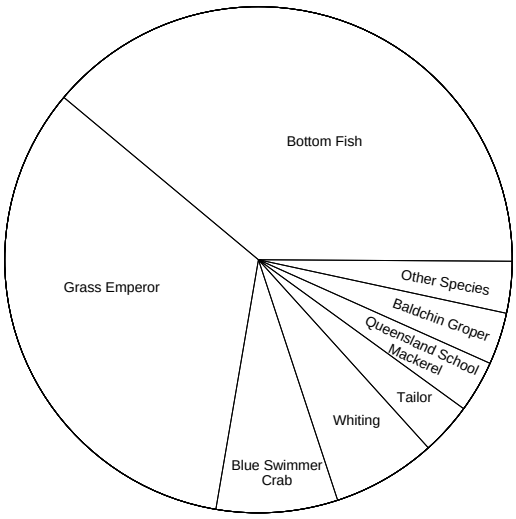
Most anglers that had launched a boat at Nanga had been targeting pink snapper (Figure 3). Anglers at Denham targeted both pink snapper and grass emperor. Grass emperor was the main species targeted by anglers at Monkey Mia. Many anglers, however, did not target a particular species. When this occurred, the interviewer recorded whether they were fishing on the surface or bottom since this determines the range of species that are likely to be caught. Anglers fishing on the bottom were likely to catch pink snapper, grass emperor and other demersal species. Few anglers fished on the surface.




Freycinet Estuary (Nanga)




Freycinet Reach (Denham)




Eastern Gulf (Monkey Mia)

**Figure 3** Species targeted by recreational fishers in Shark Bay

## 5.2 Recreational fishing effort

The estimated total recreational fishing effort for the 12-month survey was 34,000 fisher days, comprising 31,000 fisher days by boats launched from public ramps and 3,000 fisher days for boats launched from the beach at Tamala Station. This was less than the estimate of 49,000 fisher days obtained from a survey conducted during 1998-99 (Sumner *et al*., 2002) although similar to an estimate of 35,000 fisher days for 2000-01 (Sumner and Malseed, 2001). The earlier studies did not include the effort from Tamala Station. Most fishing effort occurred during winter and autumn (Figure 4).

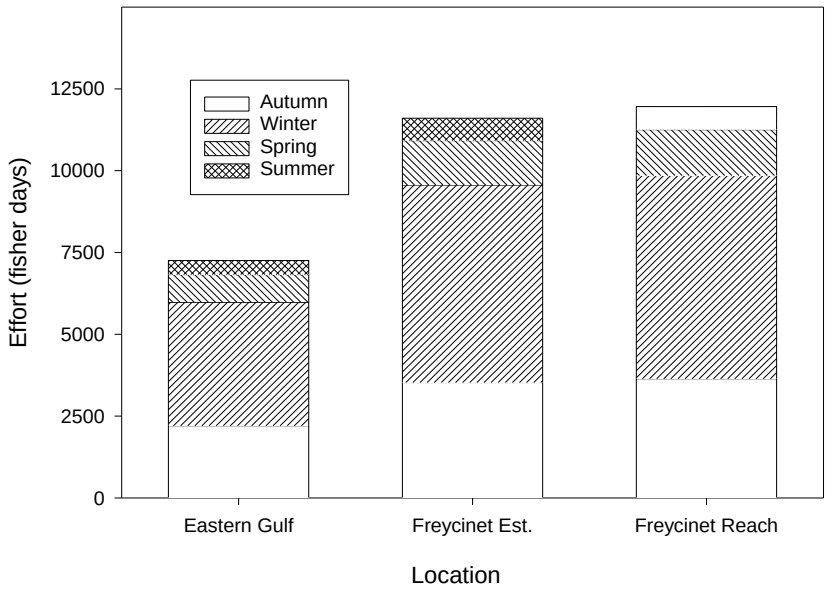



**Figure 4** Fishing effort for boats launched from public boat ramps in Shark Bay by season and location

Results indicate that most fishing occurred during the period of the day surveyed. However, fishing also occurred both before and after the daily survey period as indicated by the boat launch and retrieval times recorded by the survey interviewers. The ratio of fishing effort occurring prior to the start of the morning shift to that occurring after the start of the morning shift was estimated and a correction factor ($f$ ) applied to the effort estimate for each season (Table 1 and Appendix 6).

**Table 1** Correction factor for fishing effort occurring before the start of the daily survey period.

| Season | Ratio of effort prior to and after start of daily survey period | Correction factor ($f$) |
|---|---|---|
| Summer | 0.58 | 1.58 |
| Autumn | 0.32 | 1.32 |
| Winter | 0.27 | 1.27 |
| Spring | 0.42 | 1.42 |

On occasions there were boats remaining at the boat ramps when the interviewer's shift finished at 6:00pm. The number of boats returning after this time of the day, based on the number of trailers remaining, was relatively small (2.5 per ramp on average). Boat trailers were occasionally left at Denham while the boat crews camped at Shelter Bay (South Passage) or Dirk Hartog Island overnight. It was assumed that these boat crews did not fish at night. However, it was not possible to account for boats that returned to the ramp after 6:00pm since no catch and fishing effort information was collected beyond this time. For this reason the effort is likely to have been underestimated by the survey although this bias is likely to be small in comparison to the total effort.

### 5.3 Recreational fishing catch

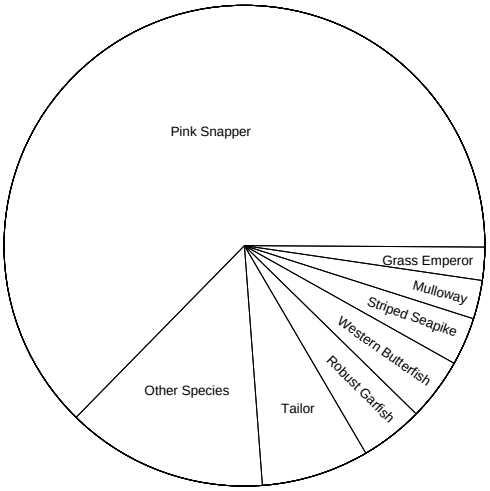
The most common species kept by recreational fishers that launched a boat from a public ramp in Shark Bay or from Tamala Station were (in order of number kept) pink snapper (*Pagrus auratus*) (8,319), grass emperor (*Lethrinus laticaudis*) (7,357), whiting species (Family *Sillaginidae*) (5,071), western butterfish (*Pentapodus vitta*) (2,605), tailor (*Pomatomus saltator*) (1,774), blue swimmer crab (Portunus pelagicus) (1,487), stripey seaperch (*Lutjanus carponotatus*) (690), large-scaled grinner (*Saurida undosquamis*) (624), Queensland school mackerel (*Scomberomorus queenslandicus*) (603) and mulloway (*Argyrosomus japonicus*) (563) (Appendix 8).

The predominant species landed at Nanga were pink snapper and tailor (Figure 5). Grass emperor, pink snapper and whiting were the most common species landed at Denham. Grass emperor, whiting and blue swimmer crabs were the most common species landed at Monkey Mia reflecting the ban on the take of pink snapper from the eastern gulf.

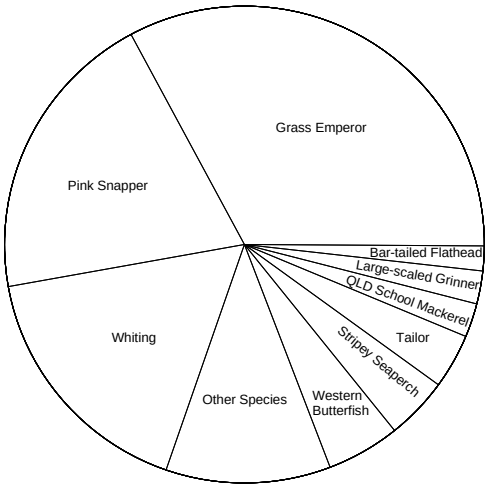
For pink snapper, grass emperor, western butterfish, large-scaled grinner, sharks, striped seapike, trumpeters, blackspot tuskfish and other species, the number of fish released was greater than the number kept. For example, ten pink snapper were released for every fish kept. Consequently, the mortality of fish caught and subsequently released is of concern (This is the focus of another project FRDC 2000/194 "Investigating survival of released undersized west coast reef fish").

The total weight of fish kept was calculated from length-weight relationships (Table 2). Species with a small total catch that could not be accurately estimated have not been reported individually.

Since catch information was not recorded after 6:00pm the catch for species caught at night has been underestimated by the survey although this bias is likely to be small in comparison to the total catch. This may have resulted in the lack of reporting for some species such as mulloway, which are known to occur in the area and are often caught at night.




Freycinet Estuary (Nanga)




Freycinet Reach (Denham)


Eastern Gulf

**Figure 5** Species composition (number of fish) of recreational catch in Shark Bay

**Table 2** Total recreational catch for the 12-month period.

| Common Name | Length-weight relationship | Source for length-weight relationship | Total weight (tonnes) |
|---|---|---|---|
| Snapper, pink | $W=4.68x10^{-2}FL^{2.78}$<br>$FL=((L-0.7)/1.179)/10$ | Moran and Burton, 1990 | 29.7 |
| Emperor, grass | $W=9.15x10^{-6}L^{3.09}$ | Keay, I. unpublished data | 7.0 |
| Mulloway | $W=3.01x10^{-5}L^{2.76}$ | Torres, 1991 | 2.8 |
| Cod, Estuary | $W=1.05x10^{-2}L(cm)^{3.084}$ | Letourneur, *et al*., 1998 | 2.0 |
| Tailor | $W=7.0x10^{-6}L^{3.05}$ | Steckis, R. unpublished data | 1.1 |
| Mackerel, Queensland School | $W=_e(3.775+0.006(FL))$<br>$FL=((TL-35.362)/1.055)$ | Cameron & Begg, unpublished data | 1.0 |
| Whiting, general[1] | $W=8.32x10^{-6}L^{2.98}$ | Hyndes, G. unpublished data | 0.8 |
| Seaperch, Stripey[2] | $W=7.720x10^{-6}FL^{3.1447}$ | Newman *et al*., 2000 | 0.6 |
| Butterfish, Western | $W=1.22x10^{-5}FL^{3.06}$<br>$FL=TL/1.117+2.347$ | Mant, unpublished data | 0.4 |
| Mullet, Sea | $W=9.35x10^{-6}L^{3.02}$ | Torres, 1991 | 0.3 |
| Crab, blue swimmer[3] | $W=2.56x10^{-5}CW^{3.260}$ | Potter *et al*., 1983 | 0.3 |
| Flathead, Bar-tailed[4] | $W=8.1x10^{-3}L(cm)^{2.92}$ | Steffe *et al*., 1996 | 0.3 |

Note: W is weight in grams; L is total length in mm; FL is fork length in mm; CW is carapace width in mm

### 5.3.1 Pink snapper

Past studies by the Department of Fisheries, Western Australia have identified that pink snapper is the main species caught by recreational fishers in the Shark Bay World Heritage Property (Sumner and Steckis 1999; Sumner and Malseed 2001; Sumner *et al*. 2002). Almost all pink snapper caught by recreational fishers in the western gulf were landed at the Nanga and Denham boat ramps (Sumner *et al*., 2002). The eastern gulf was closed to pink snapper fishing during the period when the survey was conducted.

There have been management and community concerns whether the recreational catch level from the inner gulfs of Shark Bay could be sustained. Several management measures have been introduced to protect pink snapper stocks in the inner gulfs and reduce fishing pressure from the recreational sector in recent years. In 1997 a bag limit of two pink snapper per person, a minimum size limit of 500 mm, and a maximum size of 700 mm was introduced for the eastern gulf. The eastern gulf was closed to pink snapper fishing on 9 June 1998 to enable this stock to recover from several years of intensive recreational fishing effort that led to a severely reduced breeding stock. This area remains closed to fishing for pink snapper. For the western gulf, a minimum size of 450 mm, a bag limit of four and a limit of two fish over 700 mm per person was introduced during 1997. Due to ongoing concerns for pink snapper stocks in the western gulf, revised regulations were introduced from 25 August 2000. These included a minimum size limit of 500 mm, bag limit of two and a limit of one fish over 700 mm per person. A partial closure to fishing for pink snapper in Freycinet Estuary (south of Goulet Bluff) between 15 August and 30 September, during the spawning period, was also introduced.

[1] Using relationship for yellow-fin whiting (*Silago schomburgkii*)
[2] Cleaned weight (using L as no conversion to FL available)
[3] Using relationship for males
[4] Using relationship for marbled flathead (*Platycephalus marmoratus*)

The estimated recreational catch of pink snapper during 2001-02 was 8,300 fish kept (30 tonnes). This exceeds the commercial pink snapper catch of 2 tonnes taken from the western gulf during 2001 by the Shark Bay Beach Seine and Mesh Net Managed Fishery. Almost all the recreational catch landed at Nanga and Denham was from the western gulf stock rather than the oceanic stock. The catch of oceanic snapper landed at the northern tip of Peron Peninsula and Shelter Bay (South Passage) was not included. The eastern gulf was closed to pink snapper fishing for the period when the survey was conducted.

The recently introduced management measures in the western gulf have been effective in reducing the recreational catch from 38 tonnes during 1998-99 (Table 3) to 25 tonnes in 2000-01 and 30 tonnes (including Tamala Station) in 2001-02 (Tables 4 and 5). Most of the reduction has occurred in the Freycinet Estuary where the catch was reduced from 26 tonnes in 1998-99 to 16 tonnes during 2000-01 and 22 tonnes (including Tamala Station) in 2001-02. However, despite the introduction of these new management measures, the catch of pink snapper in the Freycinet Estuary was still four times the management target of five tonnes (see section 5.4).

**Table 3** Recreational catch of pink snapper in Shark Bay from April 1998 to May 1999

| Area | Effort (fisher days) | Number Kept | Standard Error | Number Released | Weight Kept (tonnes) |
|---|---|---|---|---|---|
| Freycinet Reach (Denham) | 21,047 | 6,257 | 869 | 61,216 | 12.2 |
| Freycinet Estuary (Nanga) | 17,208 | 6,351 | 916 | 14,695 | 25.7 |
| Total western gulf | 38,255 | 12,608 | 1,263 | 75,911 | 37.9 |
| Eastern gulf[#] | 11,066 | 1,318 | 542 | 12,109 | 2.9 |

[#]Since the eastern gulf was closed to pink snapper fishing on June 9, 1998 the number kept from April 1 to June 8 is shown. The number released is for the full 12-month period.

**Table 4** Recreational catch of pink snapper in Shark Bay from May 2000 to April 2001

| Area | Effort (fisher days) | Number Kept | Standard Error | Number Released | Weight Kept (tonnes) |
|---|---|---|---|---|---|
| Freycinet Reach (Denham) | 15,753 | 4,654 | 801 | 33,831 | 9.5 |
| Freycinet Estuary (Nanga) | 9,625 | 3,733 | 562 | 11,650 | 15.8 |
| Total western gulf | 25,378 | 8,387 | 978 | 45,481 | 25.3 |
| Eastern gulf | 9,438 | 0 | - | 8,012 | 0 |

**Table 5** Recreational catch of pink snapper in Shark Bay from May 2001 to April 2002

| Area | Effort (fisher days) | Number Kept | Standard Error | Number Released | Weight Kept (tonnes) |
|---|---|---|---|---|---|
| Freycinet Reach (Denham) | 11,958 | 2,991 | 396 | 48,534* | 7.5 |
| Freycinet Estuary (Nanga) | 11,602 | 4,063 | 411 | 15,249* | 17.5 |
| Freycinet Estuary (Tamala) | 3,223 | 1,265 | 522 | 9,636 | 4.7 |
| Total western gulf | 26,783 | 8,319 | 773 | 73,419 | 29.7 |
| | | | | | |
| Eastern gulf | 7,254 | 0 | - | 14,236* | 0 |

* Size composition of released pink snapper is shown in table 6

In the western gulf the majority of pink snapper released were below the minimum legal size of 500 mm (Table 6). Considerably more undersized fish were released in Freycinet Reach than Freycinet Estuary. A small number of fish between 500 mm and 700 mm were released at both locations when anglers exceeded the bag limit on occasions. A small number of fish over 700 mm were released at both locations due to the limit of one fish over 700 mm per person.

In the eastern gulf, which is closed to the take of pink snapper, 84 percent of the pink snapper released were under 500 mm, six percent between 500 mm and 700 mm and ten percent of released pink snapper were over 700 mm. This indicates that the stock is predominantly comprised of fish less than 500 mm in length.

**Table 6** Size composition of released of pink snapper in Shark Bay from May 2000 to April 2001

| Area | Under 500mm | Between 500mm & 700mm | Over 700mm | Total |
|---|---|---|---|---|
| Freycinet Reach (Denham) | 48,122 (99.15%) | 88 (0.18%) | 323 (0.67%) | 48,534 |
| Freycinet Estuary (Nanga) | 14,998 (98.35%) | 36 (0.24%) | 216 (1.41%) | 15,249 |
| Eastern gulf (Monkey Mia) | 11,929 (83.80%) | 862 (6.06%) | 1,445 (10.15%) | 14,236 |

The size of pink snapper kept by recreational fishers had not changed greatly since 1998-99 (Tables 7, 8 and 9). Larger pink snapper were kept from the Freycinet Estuary near Nanga where anglers were targeting spawning aggregations before (Figure 6) and after (Figure 7) the size limit was increased to 500 mm on August 25, 2000. Most pink snapper kept from Freycinet Reach near Denham were just over the size limit of 450 mm before August 25, 2000 (Figure 8) or 500 mm from August 25, 2000 (Figure 9).

**Table 7** Size of pink snapper kept in Shark Bay from April 1998 to May 1999

| Area | No. Fish Measured | Mean Length (mm) | Mean Weight (kg) |
|---|---|---|---|
| Freycinet Reach (Denham) | 185 | 530 | 1.943 |
| Freycinet Estuary (Nanga) | 230 | 685 | 4.053 |
| Eastern gulf[#] | 18 | 564 | 2.231 |

[#]The eastern gulf was closed to pink snapper fishing on June 9, 1998.

**Table 8** Size of pink snapper kept in Shark Bay from May 2000 to April 2001

| Area | No. Fish Measured | Mean Length (mm) | Mean Weight (kg) |
|---|---|---|---|
| Freycinet Reach (Denham) | 102 | 542 | 2.050 |
| Freycinet Estuary (Nanga) | 170 | 699 | 4.228 |
| Eastern gulf | 0 | - | - |

**Table 9** Size of pink snapper kept in Shark Bay from May 2001 to April 2002

| Area | No. Fish Measured | Mean Length (mm) | Mean Weight (kg) |
|---|---|---|---|
| Freycinet Reach (Denham) | 136 | 584 | 2.491 |
| Freycinet Estuary (Nanga) | 199 | 706 | 4.306 |
| Freycinet Estuary (Tamala) | 39 | 671 | 3.741 |
| Eastern gulf | 0 | - | - |

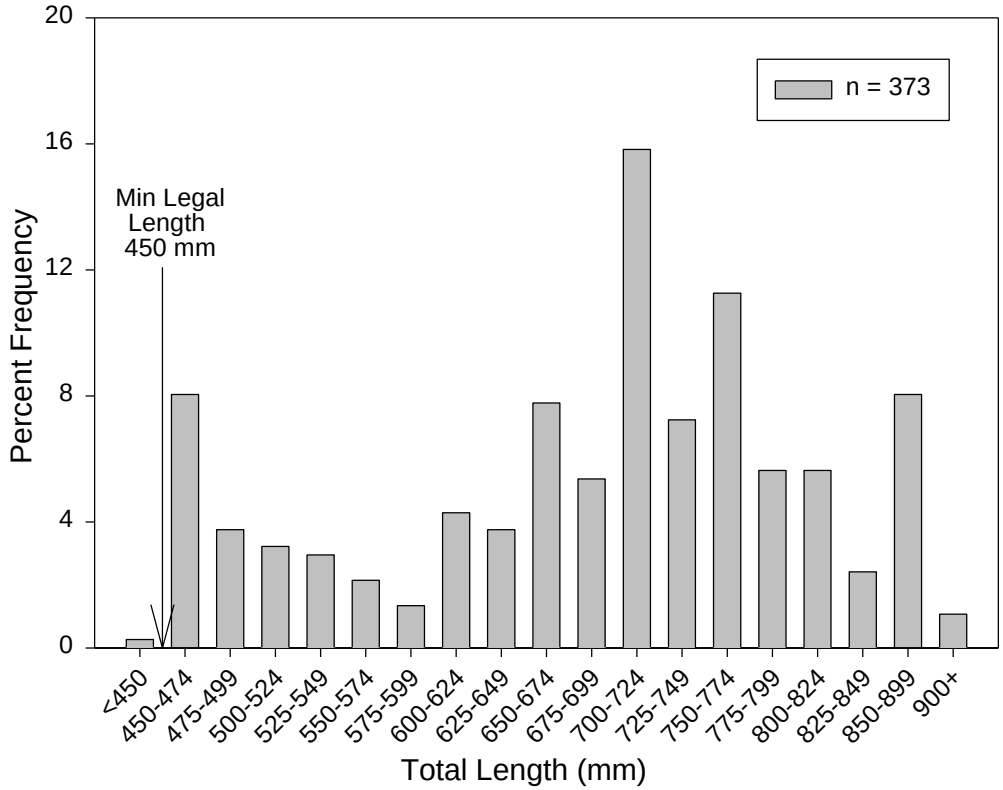



**Figure 6** Size composition of pink snapper kept from Freycinet Estuary (Nanga) (minimum length 450 mm)

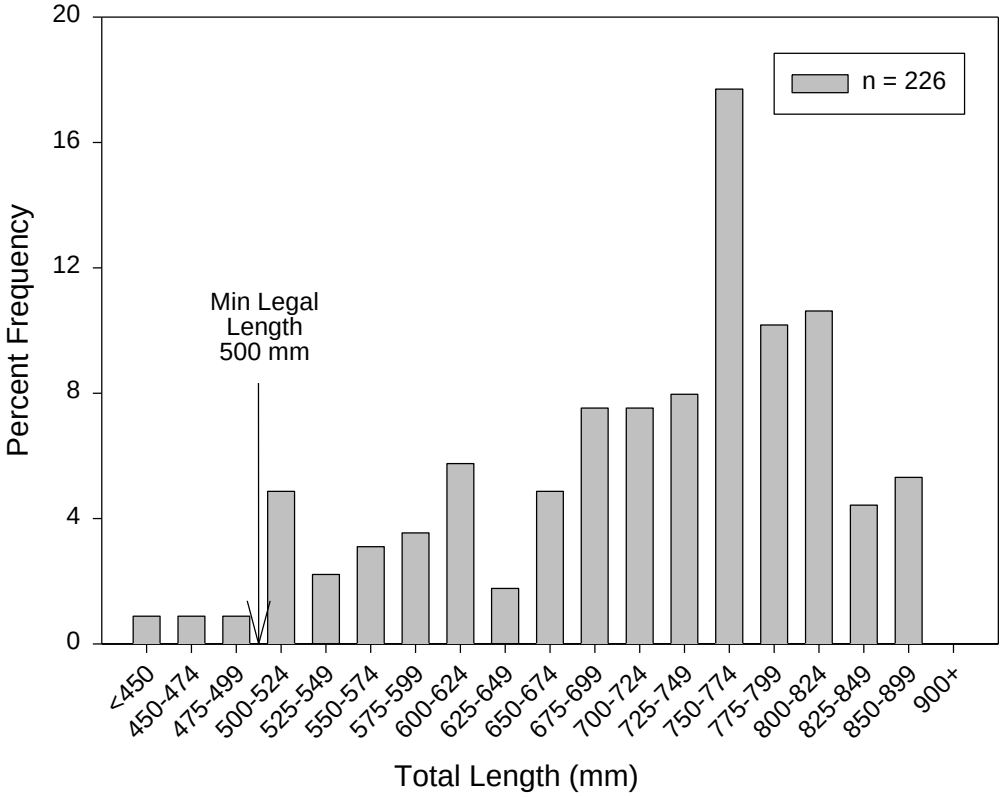



**Figure 7** Size composition of pink snapper kept from Freycinet Estuary (Nanga) (minimum length 500 mm)

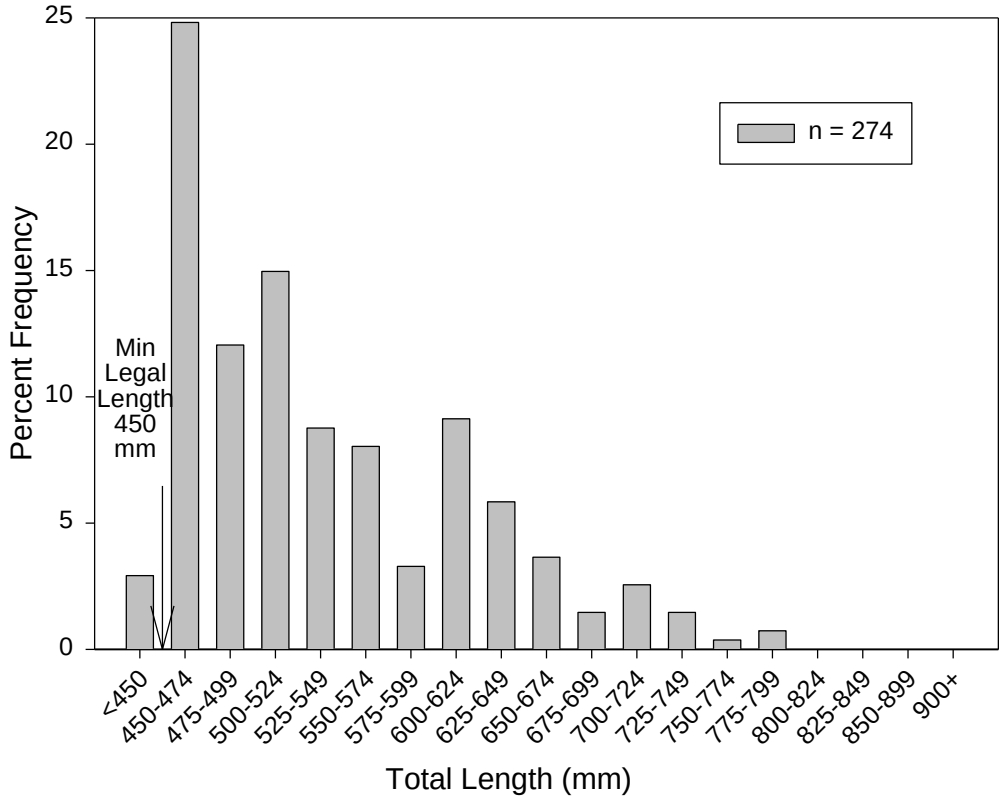



**Figure 8** Size composition of pink snapper kept from Freycinet Reach (Denham) (minimum length 450 mm)

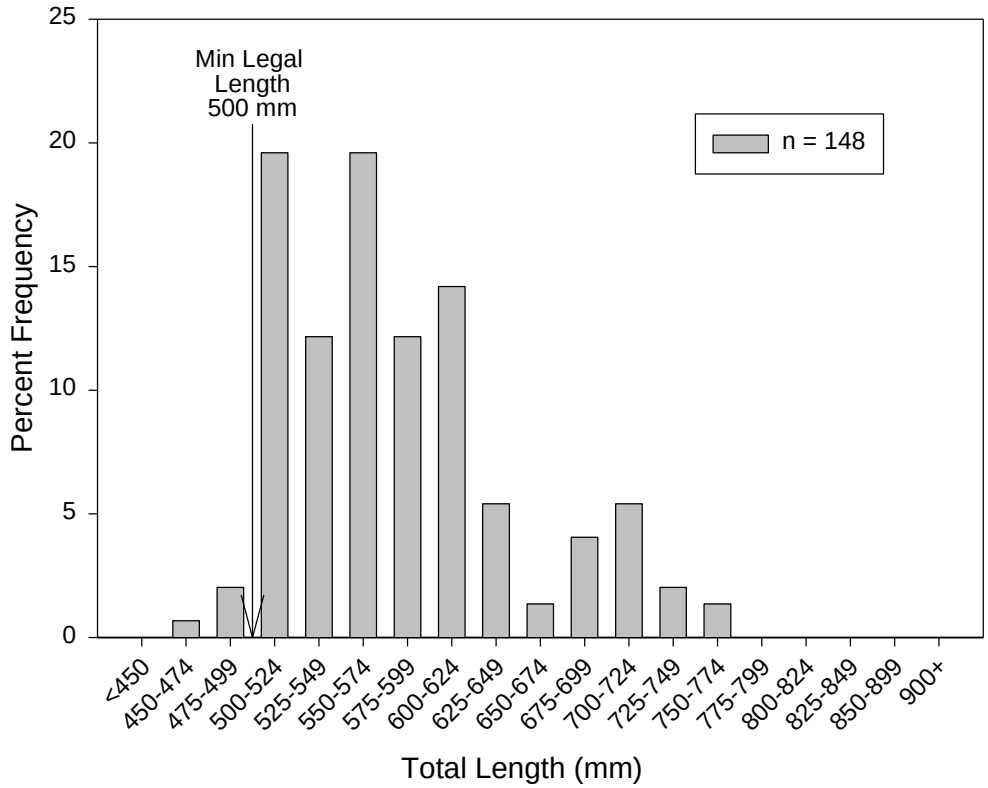



**Figure 9** Size composition of pink snapper kept from Freycinet Reach (Denham) (minimum length 500 mm)

During 1998 most of the recreational catch of pink snapper from the Freycinet Estuary occurred between July and September (Figure 10). For this reason, from 2000 the Freycinet Estuary was only open for two weeks in August due to the closure from August 15 to September 30. However, the catch for August during 2000 and 2001 was still relatively high (Figure 11). The closure effectively prevented a potentially large recreational catch occurring during September. More fishing effort occurred during July than any other month due to the school holidays. The predominant fishing effort occurred between April and October.

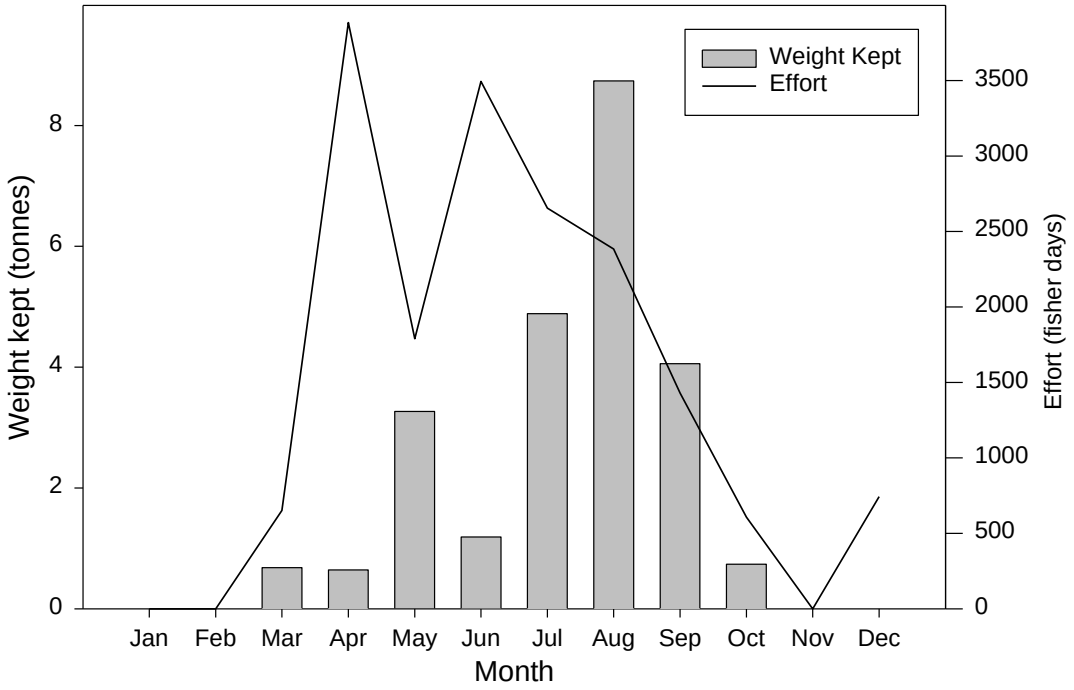



**Figure 10** Estimated catch and fishing effort for Freycinet Estuary (Nanga) pink snapper (1998)

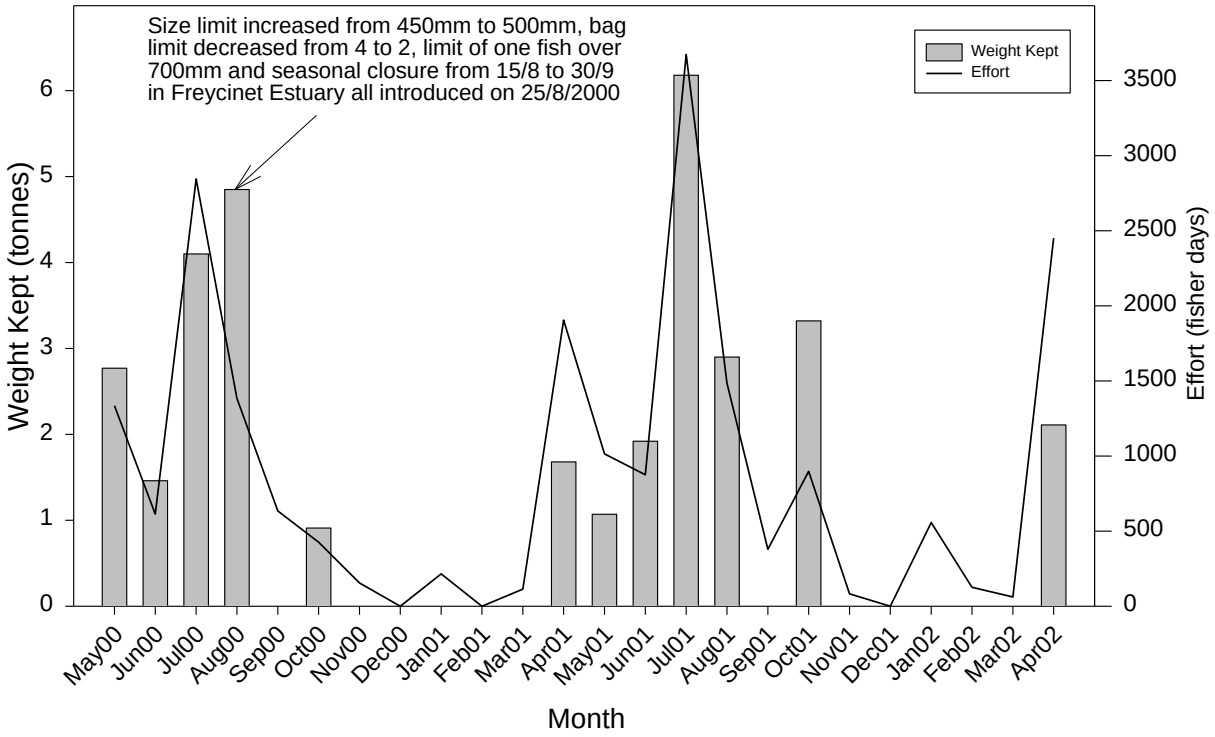



**Figure 11** Estimated catch and fishing effort for Freycinet Estuary (Nanga) pink snapper (May 2000 to April 2002)

Most of the recreational catch of pink snapper from Freycinet Reach (Denham) occurred between April and August (Figure 12). The predominant fishing effort occurred between April and August with a peak in July corresponding with the school holidays.

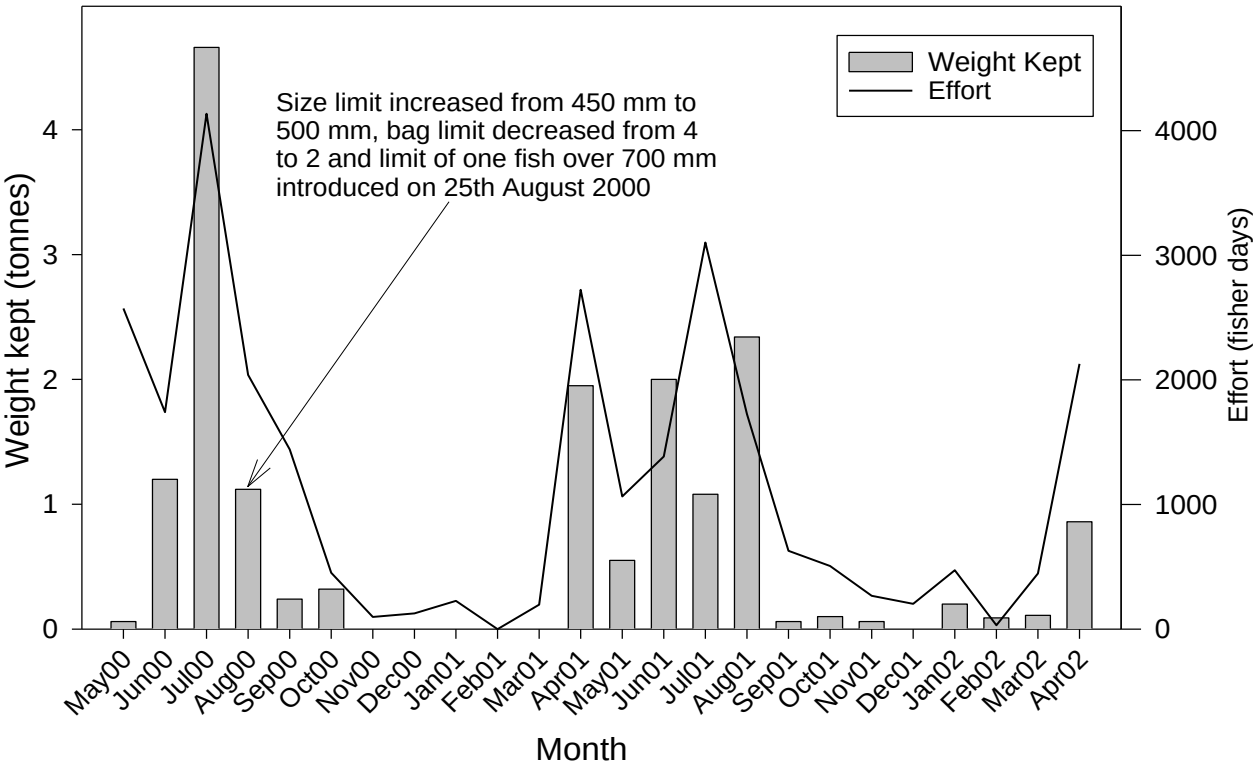



**Figure 12** Estimated catch and fishing effort for Freycinet Reach (Denham) pink snapper (May 2000 to April 2002)

*Proportion of pink snapper stock harvested by recreational fishers*

In Freycinet Estuary, results from another Department of Fisheries project monitoring the size of the breeding stock using the daily egg production method (DEPM) indicated that there was between ten and 35 tonnes of spawning stock remaining during 2001 (Jackson and Stephenson, 2002) (Table 10). The estimated catch landed at Nanga and Tamala Station was 22 tonnes with between 40% and 100% of the spawning stock harvested from the Freycinet Estuary. The spawning biomass was estimated after most of the catch was taken. This situation is critical and urgent management intervention together with continued monitoring of the catch and effort is required.

In Freycinet Reach, results from monitoring the size of the breeding stock using the daily egg production method indicate that there was between 53 and 344 tonnes of spawning stock remaining during 2001 (Jackson and Stephenson, 2002) (Table 10). The estimated catch landed at Denham was eight tonnes. Eleven percent or less of the spawning stock from Freycinet Reach was harvested. Present catch levels from Freycinet Reach are considered to be sustainable.

**Table 10** Percentage of pink snapper stock harvested by recreational fishers in Shark Bay from May 2001 to April 2002

| **Area** | **DEPM spawning biomass estimate (tonnes) 95%CI** | **Percentage of stock harvested 95%CI** |
|---|---|---|
| Freycinet Reach | 53 – 344 | 0 – 11 |
| Freycinet Estuary | 10 – 35 | 40 - 100 |
| Eastern gulf | 56 - 163 | 0 |

### 5.3.2 Grass emperor

Grass emperor (locally known as black snapper or blue-lined emperor) is predominantly a recreationally caught species. The recreational catch of grass emperor landed at the public boat ramps has decreased from 17,073 (15.9 tonnes) in 1998-99 (Sumner, *et al*., 2001) to 10,042 (11.6 tonnes) in 2000-01 (Table 11), (Sumner and Malseed, 2001) and 7,357 fish kept (7 tonnes) during 2001-02 (Table 12). The reduction in the recreational catch from 1998-99 to 2000-01 may, in part, be a consequence of reduced fishing effort due to management changes outlined above. Grass emperor was predominantly caught in Freycinet Reach (Denham) and the eastern gulf (Figure 5). Two percent of grass emperor kept were landed at Nanga.

**Table 11** Recreational catch of grass emperor in Shark Bay from May 2000 to April 2001

| Area | Effort (fisher days) | Number Kept | Standard Error | Number Released | Weight Kept (tonnes) |
|---|---|---|---|---|---|
| Western gulf (Denham & Nanga) | 25,378 | 5,425 | 936 | 11,404 | 6.0 |
| Eastern gulf (Monkey Mia) | 9,438 | 4,617 | 686 | 6,868 | 5.6 |
| Total | 34,816 | 10,042 | 1,160 | 18,272 | 11.6 |

**Table 12** Recreational catch of grass emperor in Shark Bay from May 2001 to April 2002.

| Area | Effort (fisher days) | Number Kept | S.E. | Number Released | Weight Kept (tonnes) |
|---|---|---|---|---|---|
| Western gulf (Denham, Nanga & Tamala) | 26,783 | 5,152 | 905 | 12,314 | 4.9 |
| Eastern gulf (Monkey Mia) | 7,254 | 2,205 | 320 | 3,156 | 2.1 |
| Total | 34,037 | 7,357 | 960 | 15,470 | 7.0 |

Similar sized fish were caught from the eastern gulf (Figure 13) and western gulf (Figure 14) with an average length of 379 mm at both locations (Table 13). Most fish kept were between 280 and 440 mm. Large fish were caught from both areas on occasions.

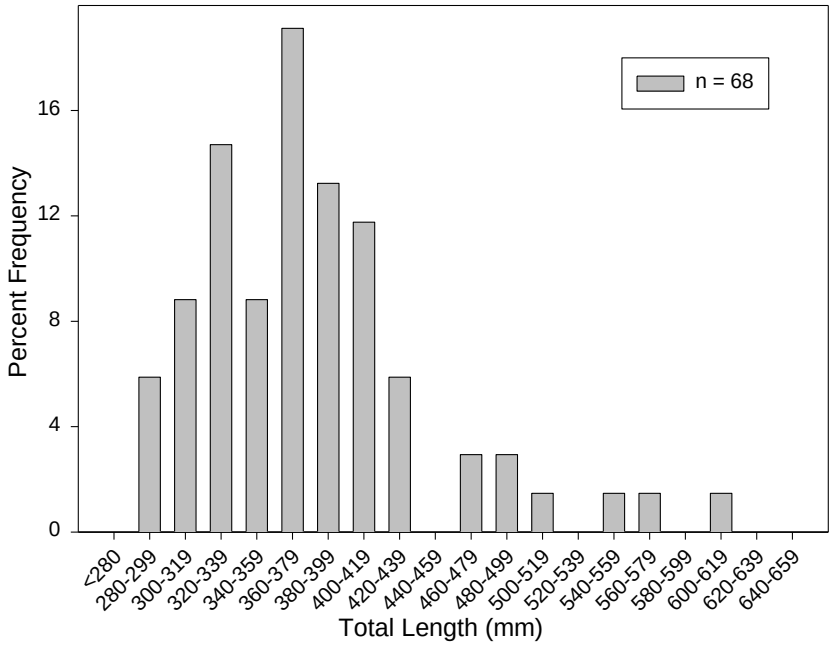



**Figure 13** Size composition of grass emperor kept from the eastern gulf (minimum length 280 mm) 2001-02

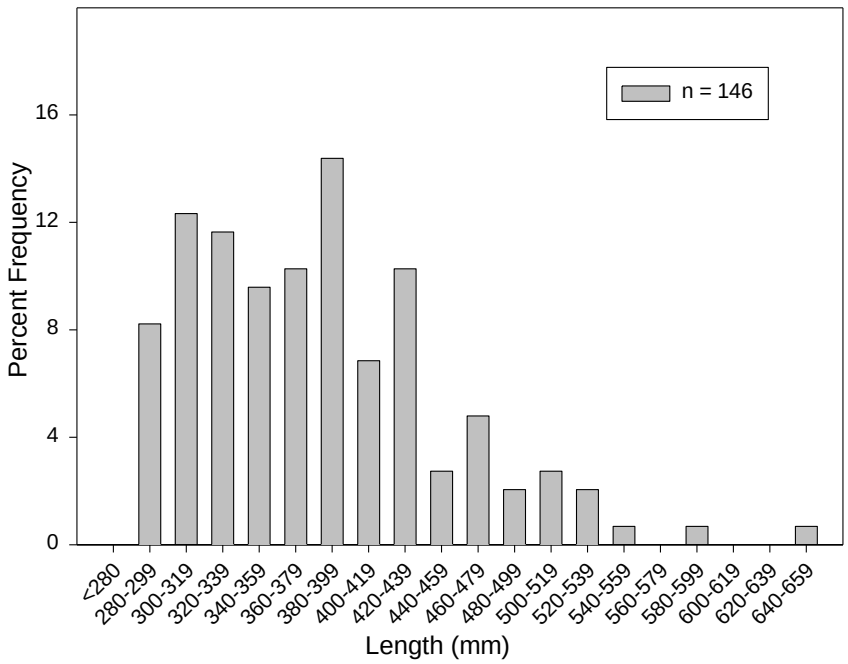



**Figure 14** Size composition of grass emperor kept from the western gulf (minimum length 280 mm) 2001-02

**Table 13** Size of grass emperor caught in Shark Bay 2001-02

| Area | No. Fish Measured | Mean Length (mm) | Mean Weight (kg) |
|---|---|---|---|
| Western gulf (Denham & Nanga) | 146 | 379 | 0.945 |
| Eastern gulf (Monkey Mia) | 68 | 379 | 0.930 |

### 5.3.3 Other species

The estimated catch of 563 (2.8 tonnes) mulloway in 2001-02 was similar to the catch of 895 (3.2 tonnes) during 2000-01 and exceeded the catch of 73 (weight not known) landed in 1998-99. The catch of 477 (2 tonnes) estuary cod was similar to the catch of 471 in 2000-01 and 518 in 1998-99. The catch of 1,774 (1.1 tonnes) tailor is similar to the catch of 1,128 (0.8 tonnes) in 2000-01 and 1,294 during 1998-99. The catch of 603 (1.0 tonnes) Queensland school mackerel is similar to the catch of 882 (1.4 tonnes) in 2000-01 and 971 for 1998-99. The catch of 690 (0.6 tonnes) stripey seaperch is greater than the catch of 363 during 2000-01 although similar to the catch of 584 during 1998-99. The recreational catch of 5,071 (0.8 tonnes) whiting exceeded the catch of 3,105 (0.4 tonnes) in 2000-01 and 3,400 landed at the three boat ramps during 1998-99. The catch of 2,605 (0.4 tonnes) western butterfish is less than the estimated catch of 3,452 (0.7 tonnes) during 2000-01 and 6,261 (2 tonnes) for 1998-99.

Variation in the recreational catch from year to year is expected due to environmental factors. The errors associated with the catch estimates may also account for much of the variation. However, the increase in the catch for species such as mulloway may be attributed to anglers targeting species other than pink snapper due to the newly introduced management measures.

## 5.4 Evaluation of the effectiveness of newly introduced management measures

The impact on the recreational catch of the revised management measures that were introduced in the western gulf was predicted using catch and effort data collected prior to their introduction. The predictions were found to be accurate when compared to catches estimated from a creel survey following the introduction of new regulations.

*Freycinet Estuary*

During the 1998-99 survey 65% of the estimated annual catch of pink snapper (by weight) were caught outside the closure between August 15 and September 30. Hence, the partial closure during this period in 2000 was expected to reduce the catch by 35%. Consequently, the predicted catch for the 2000 season was 16.7 tonnes (95% CI: 11.8 – 21.6). The catch of 15.8 tonnes for 2000 estimated from a creel survey was close to the prediction.

The new management measures introduced from August 25, 2000 included a new minimum size limit of 500 mm, a limit of one pink snapper per person over 700 mm, and a bag limit of two. The new size limit and limit of one fish over 700 mm are independent of each other.

However, the reduction in bag limit is not independent of the other measures since they were expected to make it more difficult for anglers to achieve the bag limit. P(A) = 0.96 is the proportion of the catch prior to August 25, 2000 (by weight) that complied with the new size limit and P(C) = 0.83 is the proportion of the catch (by weight) that complied with the new limit of one fish over 700 mm. Following an increase in size limit and a limit of one fish over 700 mm the reduction in bag limit (B) had no effect on the catch P(B | AC) = 1.0. Any impact of the reduced bag limit was counteracted by the other new regulations. The overall effect of the new management measures is estimated by the following formulae

$$P(A \text{ and } B \text{ and } C) = P(A) \times P(C) \times P(B \mid AC)$$

The predicted catch for 2001-02 where P(A and B and C) = 0.80 is 12.6 tonnes (95% CI: 8.8 – 16.4). This is lower than the estimated catch of 17.5 tonnes from the creel survey, however, the discrepancy can be explained by the increase in effort from 9,600 fisher days in 2000-01 to 11,600 fisher days in 2001-02. The predicted catch was 15.2 tonnes (95% CI: 10.6 – 19.8) once the increase in effort was taken into account. Thus, despite the introduction of these new management measures, the estimated catch was still four times the management target catch of five tonnes. This resulted from the high level of fishing effort, where small catches per angler accumulated over the large number of angler days resulted in a large overall catch.

The partial closure in the Freycinet Estuary was effective in reducing the recreational catch. The limit of one fish over 700 mm was also effective, however, the other management measures have been limited in their effectiveness. The new minimum size limit made little difference to the total catch by weight, however, the number of undersize fish released increased. The reduction in bag limit when accompanied with the other measures made no measurable difference to the total catch, however, the bag limit may have prevented large catches on occasions. A further reduction in bag limit to one pink snapper per person would reduce the 2001-02 recreational catch by about one quarter (P(B) = 0.76). A partial closure from 1st June to 31st October together with a bag limit of one pink snapper per person is required to reduce the combined catch from Nanga and Tamala Station to the management target of 5 tonnes.

*Freycinet Reach*

Applying the new management measures to the catch data prior to August 25, 2000. P(A) = 0.75 was the proportion of the catch (by weight) that complied with the new size limit. Almost all (P(C) = 0.99) of the catch (by weight) complied with the new limit of only one fish over 700 mm. The additional impact of a reduction in bag limit following an increase in size limit and a limit of one fish over 700 mm resulted in P(B | AC) = 0.91. The overall effect of the new management measures was P(A and B and C) = 0.68. Applying this proportion to the 2000 catch the predicted catch for Freycinet Reach in 2001 was 6.5 tonnes (95% CI: 4.3 – 8.7). The estimated catch of 7.5 tonnes from the creel survey is within the 95% confidence interval, however, the reduction in effort from 15,800 fisher days in 2000-01 to 12,000 fisher days in 2001-02 has not been taken into account.

Some, but not all of the new management measures, were effective in reducing the recreational catch. The new minimum size limit reduced the catch by one quarter with a corresponding increase in the number of undersize fish released. The limit of only one fish over 700 mm made no difference due to the predominantly smaller fish landed at Denham. The reduction in bag limit when accompanied with the other measures made little difference to the total catch in tonnes, however, the bag limit prevented large catches on occasions.

A further reduction in bag limit to one pink snapper per person would reduce the 2001-02 recreational catch by about one third (P(B) = 0.68).

### 5.5 Equipment used by fishers

Anglers have adopted modern technology to increase the efficiency of recreational fishing with 78% percent of boats launched at public boat ramps fitted with an echo-sounder and 65% using a global positioning system to find fishing locations. Few boats had snapper winches fitted (4%). Most boats had a marine band radio fitted (78%).

The global positioning systems and echo sounders enable boat crews to easily locate fishing grounds and return to the same ground on future trips. This increases the efficiency of recreational fishers by enabling anglers to effectively target a range of species as well as increasing the catch rates for these species.

### 5.6 Compliance with recreational fishing regulations

There was a very high level of compliance with the fishing regulations. Only 8 (2%) of the 414 boat crews interviewed at boat ramps that had been fishing had kept under size fish. Very few fishers exceeded the bag limits.

## 6.0 Benefits

The information provided by this study will be crucial for the community consultative process set-up by the Department of Fisheries WA to recommend future management measures for Shark Bay to the Minister. Industry and recreational fishers will both benefit from the improved quality of management that will be possible with a clearer understanding of recreational catch and effort in Shark Bay.

In addition to the data collection role, the survey interviewers also performed a community awareness role. Recreational fishers benefited from having Department of Fisheries WA staff at the boat ramps to advise them of the fishing regulations and hand out brochures and fish rulers. Following the interview, recreational fishers were more aware of the critical status of pink snapper stocks, the management issues and the reasons for conducting the survey.

Fisheries managers in some other states will find the results of comparative value.

## 7.0 Further development

Additional monitoring beyond the previous study, funded by the Fisheries Research Development Corporation, which finished in June 2002 is required to estimate changes to the total catch, catch rates, size composition and mortality of pink snapper and other exploited

marine species. This information, together with other studies to estimate the size of the pink snapper stocks, is required to monitor the recreational catch and develop management strategies. The strategies will facilitate the proper management of fish stocks in the Shark Bay World Heritage Property and ensure the sustainability of fishing activities and conservation of fish stocks and fish habitat.

These recommendations have already been adopted by the Department of Fisheries WA with the continuation of recreational catch monitoring beyond this study. This study has highlighted the limitations of traditional management measures such as size and bag limits. For this reason, two new management methods to limit the recreational catch of pink snapper, 1) issuing a limited number of tags required for fish kept; and 2) closing the fishery once the catch allocation has been achieved, are now being implemented for the inner gulf stocks within Shark Bay.

# 8.0 Conclusions

The new management measures introduced in the western gulf have had only limited success in reducing the recreational pink snapper catch from Freycinet Estuary and Freycinet Reach to sustainable levels. Due to the high level of fishing effort, small catches per angler accumulated over the large number of angler days resulted in a large overall catch. Consequently, despite the introduction of new management measures, the estimated catch of pink snapper in Freycinet Estuary was four times the management target catch of five tonnes.

The limited effectiveness of the recently introduced management measures indicates that small and vulnerable stocks such as the inner gulf pink snapper stocks in Shark Bay cannot be effectively managed using standard techniques such as size and bag limits. Traditional recreational management methods based on size and bag limits did not reduce the catch in Freycinet Estuary to a sustainable level. Furthermore, due to the minimum size limit, large numbers of pink snapper are being caught and subsequently released particularly in Freycinet Reach. Consequently, the mortality of fish caught and subsequently released is of concern (This is the focus of another project FRDC 2000/194 “Investigating survival of released undersized west coast reef fish”). These problems will provide challenges for the management of this and other similar recreational fisheries.

In Freycinet Estuary, results from another Department of Fisheries project (Jackson and Stephenson, 2002) monitoring the size of the breeding stock using the daily egg production method indicate that there was between ten and 35 tonnes of spawning stock remaining during 2001. The estimated catch landed at Nanga and Tamala Station was 22 tonnes. Therefore, the situation is critical and urgent management intervention together with continued monitoring of the catch and effort is required.

In Freycinet Reach, the size of the breeding stock was between 53 and 344 tonnes of spawning stock remaining during 2001. The estimated catch landed at Denham was eight tonnes. Present catch levels from Freycinet Reach are considered to be sustainable.

The closure of the eastern gulf of Shark Bay to pink snapper fishing is enabling this stock to recover from several years of intensive recreational fishing that led to a severely reduced breeding stock. The eastern gulf will remain closed until the stock returns to a sustainable level. This situation is being monitored by the Department of Fisheries WA.

Additional monitoring beyond this study, funded by Fisheries Research and Development Corporation, which finished in June 2002 is required to monitor the recreational catch of pink snapper. Furthermore, the recreational catch from the eastern gulf will need to be closely monitored to ensure that overfishing does not occur once this fishery is reopened. The management strategies developed from the results provided by this study will facilitate the proper management of fish stocks in the Shark Bay World Heritage Property and help ensure the sustainability of fishing activities and conservation of fish stocks and fish habitat.

# 9.0 References


Anonymous, 1999. Mathcad 2000 Professional. Mathsoft Inc., Cambridge, MA, USA.

Crone, P.R. and Malvestuto, S.P., 1991. Comparison of five estimators of fishing success from creel survey data on three Alabama reservoirs. In Guthrie, D., Hoenig, J.M., Holliday, M., Jones, C.M., Mills, M.J., Moberly, S.A., Pollock, K.H. and Talhelm, D.R. (Ed.) Creel and angler surveys in fisheries management. American Fisheries Society Symposium **12**: 61-66.

Edmonds, J.S., Moran, M.J., Caputi, N. and Morita, M., 1989. Trace element analysis of fish sagittae as an aid to stock identification: pink snapper (*Chrysophrys auratus*) in Western Australian waters. *Can. J. Fish. Aquat. Sci*. **46**(1): 50-54.

Jackson, G. and Stephenson, P., 2002. Progress report on status of inner Shark Bay pink snapper (Pagrus auratus) prepared for ministerial working group. Dept. of Fisheries WA Report, 47p

Johnson, M.S., Creagh, S. and Moran, M., 1986. Genetic subdivision of stocks of snapper, *Chrysophrus unicolor*, in Shark Bay, Western Australia. *Aust. J. Freshw. Res*. **37**: 337-45.

Jones, C.M. and Robson, D.S., 1991. Improving precision in angler surveys: traditional access design versus bus route design. In Guthrie, D., Hoenig, J.M., Holliday, M., Jones, C.M., Mills, M.J., Moberly, S.A., Pollock, K.H. and Talhelm, D.R. (Ed.) Creel and angler surveys in fisheries management. American Fisheries Society Symposium **12**: 177-188.

Jones, C.M., Robson, D.S., Otis, D. and Gloss, S., 1990. Use of a computer simulation model to determine the behaviour of a new survey estimator for recreational angling. *Trans. Am. Fisheries Soc*. **119**: 41-54.

Kendall, M.G. and Stuart, A., 1969. The Advanced Theory of Statistics. Vol. 1. Distribution Theory. p. 232. Charles Griffin, London.

Letourneur, Y., Kulbicki, M. and Labrosse, P., 1998. Length-weight relationships of fish from coral reefs and lagoons of New Caledonia, southwestern Pacific Ocean: an update.. Naga, ICLARM Q. **21**(4): 39-46.

McGlennon, D. and Kinloch, M.A., 1997. Resource allocation in the South Australian marine scalefish fishery. South Australian Research and Development Institute 93/249.

Moran, M., 1987. Tagging confirms separate stocks of snapper in Shark Bay region. *Fins* **20**(4): 3-9.

Moran, M.J. & Burton, C., 1990. Relationships among partial and whole lengths and weights for Western Australian pink snapper *Chrysophrys auratus* (Sparidae) – Dept. of Fisheries WA Research Report No. **89**, 13p.

Neter, J., Wasserman, W. and Whitmore, G.A., 1988. Applied Statistics. 3rd edition. Allyn and Bacon, Boston. 1006p.

Newman, S.J., Cappo, M. and Williams, D.McB., 2000. Age, growth and mortality of the stripey, *Lutjanus carponotatus* (Richardson) and the brown-stripe snapper, *L. vitta* (Quoy and Gaimard) from the central Great Barrier Reef, Australia. *Fisheries Research* **48** (3): 263-275.

Pollock, K.H., Jones, C.M. and Brown, T.L., 1994. Angler survey methods and their application in fisheries management. American Fisheries Society Special Publication 25. 371p.

Potter, I.C., Chrystal, P.J. and Loneragan, N.R., 1983. The biology of the blue manna crab *Portunus pelagicus* in an Australian estuary, *Marine Biology*, **78**: 75-85.

Robson, D.S. and Jones, C.M., 1989. The theoretical basis of an access site angler survey design. *Biometrics* **45**: 83-96.

Steffe, A.S., Murphy, J.J., Chapman, D.J., Tarlinton, B.E., Gordon, G.N.G. and Grinberg, A., 1996. An assessment of the impact of offshore recreational fishing in New South Wales waters on the management of commercial fisheries. FRDC Final Report, Project 94/053, 69pp.

Sumner, N.R. and Steckis R.A., 1999. Statistical analysis of Gascoyne region recreational fishing study July 1996. Dept. of Fisheries WA Research Report No. 115, 30p.

Sumner, N.R. and Malseed, B.E. (2001). A 12 month survey of recreational fishing in Shark Bay during 2000-01. Commonwealth World Heritage Project report by Dept. of Fisheries WA. 32p.

Sumner, N.R., Williamson, P.C. and Malseed, B.E. (2002). A 12 month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. Dept. of Fisheries WA Research Report No. 139, 54p.

Torres, F. jr (1991). Tabular data on marine fishes from Southern Africa, Part I: Length-Weight Relationships, *Fishbyte* 9: 50-53.

# Appendix 1: Intellectual property

Based on the share of funding, the proportion of ownership of the project intellectual property is the Department of Fisheries WA 56% and FRDC 44%.

# Appendix 2: Staff

| | |
|---|---|
| Principal Investigator | Neil Sumner |
| Project Coordinator | Ben Malseed |
| Database Administrator | Peta Williamson |
| Data Entry | Maria Tassone |
| Survey Interviewer | Kim Gray |

# Appendix 3: Boat ramp trailer count form

**Interviewer's Name:** _____

**Date:** _____ **Start Time(24hr):** _____ **Finish Time(24hr):** _____

**Area:** _____ **Boat Ramp:** _____

**ENVIRONMENTAL DATA**

| **Wind:** | **Calm 1** | **Light 2** | **Mod 3** | **Strong 4** | **Gale 5** | **Direction** |
|---|---|---|---|---|---|---|

| **Water:** | **Calm 1** | **Slight 2** | **Mod 3** | **Rough 4** | **V. Rough 5** |
|---|---|---|---|---|---|

| **Cloud Cover:** | **Cloud %** | **Rainfall:** | **Nil 1** | **Light 2** | **Mod 3** | **Heavy 4** |
|---|---|---|---|---|---|---|

| **Boat Launches** | | | | **Boat Retrievals** | | | | **Total Number of Trailers** | |
|---|---|---|---|---|---|---|---|---|---|
| **Time** | **Type** | **Time** | **Type** | **Time** | **Type** | **Time** | **Type** | **At Start** | **At Finish** |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Boat Types
P: Power boat
Y: Yacht
O: Other

# Appendix 4: Boat ramp interview questionnaire form

**Date: _____ Location: _____ Boat Reg. No.:_____**

| Interview Time | Boat (Pwr/Yacht/Othr) | Boat Departure Time | Fish/Dive/Snorkel/Other | Number in Boat | Number of Females in Boat | Age Group of Interviewee | Home Postcode of Interviewee | Length of Boat (ft/m) | Member Angling Club (Yes/No) | Time Spent Fishing (decimal hrs) | Block Number | Shark Bay Region – Denham, Monkey Mia, Nanga, Oceanic | Number of Lines Used | Number and type of nets - Crab,Set, Haul,cAst, Pots | Number of Times Interviewed Before |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |

**FISHERS ONLY**

| Species | Number Kept | Number Released | Number under 50cm Released | Number over 70cm Released | Taken by Sharks | Under/Over Size Kept | Species Targeted<br>1._____<br>2._____<br>Measurements (mm) |
|---|---|---|---|---|---|---|---|
| Pink Snapper | | | | | | | |
| | | | | | | | |
| Black Snapper | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

# Appendix 4: Boat ramp interview questionnaire form (continued)

1. Does your boat have any of the following equipment:

| | | | |
|---|---|---|---|
| Black and white echo sounder (Yes/No) | | Radar(Yes/No) | |
| Colour echo sounder(Yes/No) | | Marine Band Radio(Yes/No) | |
| Global Positioning System(Yes/No) | | Number of Snapper winches | |

2. What is the size limit for _____*targeted/predominant species from catch*?

| **Correct** | **Incorrect** | **Don't Know** |
|---|---|---|

3. What is the bag limit for _____*targeted/predominant species from catch*?

| **Correct** | **Incorrect** | **Don't Know** |
|---|---|---|

# Appendix 5: Shore patrol interview questionnaire form

FISHERIES
WESTERN AUSTRALIA

## Shark Bay Region Shore Survey 2001/02

Officer's Name: _____

Area: Shark Bay

Patrol: Tamala Station

Location: _____

Date: ____/____/____

Time (24hr): _____

Number groups camped: _____

Number boats not fishing: _____

Number boats fishing: _____

Number shore fishers: _____

### WIND

| Calm | Light | Mod | Strong | Gale |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

Direction: _____

### WATER

| Calm | Slight | Mod | Rough | V. Rough |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

### CLOUD COVER & RAINFALL

| Cloud % | Nil | Light | Moderate | Heavy |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |

### LENGTHS OF RANDOM SAMPLE (mm)

Species: _____

Lengths: _____

Species: _____

Lengths: _____

Species: _____

Lengths: _____

Species: _____

Lengths: _____

Species: _____

**Fishing Today**

**Y**: Completed fishing
**N**: Not fishing today
**F**: Fishing currently
**L**: Will fish later

**Gear Types**

DR: Drop net (crab)
SE: Set (or gill ) net
HA: Haul (or drag ) net
CA: Cast (or throw ) net
PO: Pot (rock lobster)
SC: Scoop (crab, prawn )
SN: Snare (rock lobster )
HO: Hook (rock lobster or crab)
SP: Spear

| Group Number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Home postcode | | | | |
| Number in group | | | | |
| Times interviewed before | | | | |
| Fishing today (Y/N/F/L) | | | | |
| Fishing yesterday(Y/N/E) | | | | |
| **B**oat/**S**hore/**D**ive/s**N**orkel | | | | |
| Number persons fishing | | | | |
| Time spent fishing(decimal hours) | | | | |
| Number of lines used | | | | |
| Gear (Number & Type) | | | | |
| Species Targeted | | | | |
| **Species 1** | Pink Snapper | Pink Snapper | Pink Snapper | Pink Snapper |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Under/Over size kept | | | | |
| **Species 2** | Black Snapper | Black Snapper | Black Snapper | Black Snapper |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Under/Over size kept | | | | |
| **Species 3** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Under/Over size kept | | | | |
| **Species 4** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Under/Over size kept | | | | |
| **Species 5** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Under/Over size kept | | | | |
| **Species 6** | | | | |
| Total number kept | | | | |
| Number released | | | | |
| Number lost to sharks | | | | |
| Under/Over size kept | | | | |

# Appendix 6: Catch and effort calculations for boats launched from public boat ramps

**Estimation of total effort**

The fishing effort for a day (hours) was estimated by the method of Jones and Robson (1991) as follows:

$$e = fT\sum_i \left[ \left( \frac{1}{w_i} \right) \sum_j X_{ij} \right] \qquad (1)$$

where $T$=8 is the time taken to complete the bus route, $w_i$ is the interviewer wait time at site $i$ and $X_{ij}$ is the time trailer $j$ spends at site $i$. A correction factor $f \geq 1$ was used to adjust the effort for fishing that occurred before the morning shift commenced at time $t$.

$$f = \frac{\sum_j (r_j - \ell_j)}{\sum_j b_j} \qquad (2)$$

where

$$b_j = \begin{cases} r_j - t, & \ell_j < t \\ r_j - \ell_j, & \ell_j \geq t \end{cases}$$

$r_j$ is the retrieval time for boat $j$ and $\ell_j$ is the launch time for boat $j$. The fishing effort was estimated for a random sample of days in each stratum (see Section 2.2). The estimated variance within stratum $k$ is (Pollock *et al*., 1994)

$$s_k^2 = \frac{1}{n_k - 1} \sum_{m=1}^{n_k} \left( e_{km} - \bar{e}_k \right)^2 \qquad (3)$$

where $n_k$ is the sample size (days) for stratum $k$, $e_{km}$ the effort for stratum $k$ on day $m$ and $\bar{e}_k$ the mean daily fishing effort for stratum $k$. The variance associated with the estimate of the mean, with finite population correction (Neter *et al*., 1988), is calculated as

$$Var(\bar{e}_k) = \frac{s_k^2}{n_k} \left( \frac{N_k - n_k}{N_k} \right) \qquad (4)$$

where $N_k$ is the total number of days in stratum $k$. The total effort for stratum $k$ is estimated as

$$\hat{E}_k = \frac{N_k}{n_k} \sum_{m=1}^{n_k} e_{km} \qquad (5)$$

The variance associated with $\hat{E}_k$ is estimated by

$$Var(\hat{E}_k) = N_k^2 \, Var(\bar{e}_k) \qquad (6)$$

The standard error is calculated by the usual method

$$SE(\hat{E}_k) = \sqrt{Var(\hat{E}_k)} \qquad (7)$$

The total effort is estimated by summing the effort for the strata as follows

$$\hat{E} = \sum_{k=1}^{n} \hat{E}_k \qquad (8)$$

where *n* is the number of strata. Similarly the variance of $\hat{E}$ is estimated from the independent variances for the strata

$$Var(\hat{E}) = \sum_{k=1}^{n} Var(\hat{E}_k) \qquad (9)$$

The standard error of $\hat{E}$ is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \qquad (10)$$

**Estimation of total catch**

The catch rate for each stratum *k* is estimated by (Crone and Malvestuto, 1991) since the probability of sampling a boat is independent of trip length

$$\hat{R}_k = \frac{\bar{c}_k}{\bar{L}_k} = \frac{\sum_{j=1}^{n_k} c_{kj} / n_k}{\sum_{j=1}^{n_k} L_{kj} / n_k} \qquad (11)$$

where $n_k$ is the number of boats where the catch was recorded, $c_{kj}$ the catch for boat *j* and $L_{kj}$ the effort, in hours, for boat *j*. The variances for $\bar{c}_k$ and $\bar{L}_k$ can be calculated by the usual method (see (3) and (4) without the finite population correction factor). The variance for $\hat{R}_k$ can be estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{R}_k) \approx \hat{R}_k^2 \left( \frac{Var(\bar{c}_k)}{\bar{c}_k^2} + \frac{Var(\bar{L}_k)}{\bar{L}_k^2} - \frac{2Cov(\bar{c}_k, \bar{L}_k)}{\bar{c}_k \bar{L}_k} \right) \qquad (12)$$

The covariance term was assumed to be zero.

The total catch for stratum *k* is estimated as

$$\hat{C}_k = \hat{E}_k \hat{R}_k \qquad (13)$$

The variance was estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{C}_k) \approx \hat{C}_k^2 \left( \frac{Var(\hat{E}_k)}{\hat{E}_k^2} + \frac{Var(\hat{R}_k)}{\hat{R}_k^2} + \frac{2Cov(\hat{E}_k, \hat{R}_k)}{\hat{E}_k \hat{R}_k} \right) \qquad (14)$$

where the covariance term was assumed to be zero. The total catch is estimated by summing the catch for each strata as follows

$$\hat{C} = \sum_{k=1}^{n} \hat{C}_k \qquad (15)$$

The variance of $\hat{C}$ is estimated as

$$Var(\hat{C}) = \sum_{k=1}^{n} Var(\hat{C}_k) \qquad (16)$$

The standard error of $\hat{C}$ is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \qquad (17)$$

# Appendix 7: Catch and effort calculations for boats launched from Tamala Station

### Estimation of total effort

The fishing effort (hours) was estimated by the roving creel survey method (Pollock *et al*., 1994) as follows:

$$e = IT \qquad (1)$$

where $I$ is the count of boats and $T$=9 is the length of the shift. The estimated variance within stratum $k$ is (Pollock *et al*., 1994)

$$s_k^2 = \frac{1}{n_k - 1}\sum_{m=1}^{n_k}\left(e_{km} - \bar{e}_k\right)^2 \qquad (2)$$

where $n_k$ is the sample size (days) for stratum $k$, $e_{km}$ the effort for stratum $k$ on day $m$ and $\bar{e}_k$ the mean daily fishing effort for stratum $k$. The variance associated with the estimate of the mean, with finite population correction (Neter *et al*., 1988), is calculated as

$$Var(\bar{e}_k) = \frac{s_k^2}{n_k}\left(\frac{N_k - n_k}{N_k}\right) \qquad (3)$$

where $N_k$ is the total number of days in stratum $k$. The total effort for stratum $k$ is estimated as

$$\hat{E}_k = \frac{N_k}{n_k}\sum_{m=1}^{n_k} e_{km} \qquad (4)$$

The variance associated with $\hat{E}_k$ is estimated by

$$Var(\hat{E}_k) = N_k^2\, Var(\bar{e}_k) \qquad (5)$$

The standard error is calculated by the usual method

$$SE(\hat{E}_k) = \sqrt{Var(\hat{E}_k)} \qquad (6)$$

The total effort is estimated by summing the effort for each strata as follows

$$\hat{E} = \sum_{k=1}^{n} \hat{E}_k \qquad (7)$$

where $n$ is the number of strata. Similarly the variance of $\hat{E}$ is estimated as

$$Var(\hat{E}) = \sum_{k=1}^{n} Var(\hat{E}_k) \qquad (8)$$

The standard error of $\hat{E}$ is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \tag{9}$$

**Estimation of total catch**

The catch rate for each stratum *k* is estimated by (Crone and Malvestuto, 1991) since the probability of sampling a boat is independent of trip length

$$\hat{R}_k = \frac{\bar{c}_k}{\bar{L}_k} = \frac{\sum_{j=1}^{n_k} c_{kj} / n_k}{\sum_{j=1}^{n_k} L_{kj} / n_k} \tag{10}$$

where $n_k$ is the number of boats where the catch was recorded, $c_{kj}$ the catch for boat $j$ and $L_{kj}$ the effort, in hours, for boat $j$. The variances for $\bar{c}_k$ and $\bar{L}_k$ can be calculated by the usual method (see (2) and (3) without the finite population correction factor). The variance for $\hat{R}_k$ can be estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{R}_k) \approx \hat{R}_k^2 \left( \frac{Var(\bar{c}_k)}{\bar{c}_k^2} + \frac{Var(\bar{L}_k)}{\bar{L}_k^2} - \frac{2Cov(\bar{c}_k, \bar{L}_k)}{\bar{c}_k \bar{L}_k} \right) \tag{11}$$

The covariance term was assumed to be zero. The total catch for stratum *k* is estimated as

$$\hat{C}_k = \hat{E}_k \hat{R}_k \tag{12}$$

The variance was estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{C}_k) \approx \hat{C}_k^2 \left( \frac{Var(\hat{E}_k)}{\hat{E}_k^2} + \frac{Var(\hat{R}_k)}{\hat{R}_k^2} + \frac{2Cov(\hat{E}_k, \hat{R}_k)}{\hat{E}_k \hat{R}_k} \right) \tag{13}$$

where the covariance term was assumed to be zero. The total catch is estimated by summing the catch for each strata as follows

$$\hat{C} = \sum_{k=1}^{n} \hat{C}_k \tag{14}$$

The variance of $\hat{C}$ is estimated as

$$Var(\hat{C}) = \sum_{k=1}^{n} Var(\hat{C}_k) \tag{15}$$

The standard error of $\hat{C}$ is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \tag{16}$$

# Appendix 8: Recreational catch from boats in Shark Bay

| Common name | Scientific name | No. kept | SE kept | No. released |
|---|---|---|---|---|
| Snapper, pink | *Pagrus auratus* | 8,319 | 773 | 87,655 |
| Emperor, grass | *Lethrinus laticaudis* | 7,357 | 1,281 | 15,470 |
| Whiting, general | Family – Sillaginidae | 5,071 | 1,850 | 203 |
| Butterfish, western | *Pentapodus vitta* | 2,605 | 610 | 9,508 |
| Tailor | *Pomatomus saltator* | 1,774 | 587 | 128 |
| Crab, blue swimmer | *Portunus pelagicus* | 1,487 | 668 | 622 |
| Seaperch, stripey | *Lutjanus carponotatus* | 690 | 233 | 428 |
| Grinner, large-scaled | *Choerodon rubescens* | 624 | 146 | 1,604 |
| Mackerel, Queensland school | *Scomberomorus queenslandicus* | 603 | 90 | 169 |
| Mulloway | *Argyrosomus hololepidotus* | 563 | 492 | 115 |
| Mullet, Sea | *Mugil cephalus* | 550 | 479 | 0 |
| Shark, general | Family – Carcharhinidae | 547 | 727 | 1,302 |
| Flathead, bar-tailed | *Platycephalidae endrachtensis* | 542 | 503 | 219 |
| Cod, estuary | *Epinephelus coioides* | 477 | 85 | 226 |
| Garfish, general | Family – Hemiramphidae | 446 | 535 | 0 |
| Seapike, striped | *Sphyraena obtusata* | 441 | 502 | 525 |
| Trumpeters/grunters | Family – Terapontidae | 381 | 202 | 1,554 |
| Tuskfish, blackspot | *Choerodon schoenleinii* | 260 | 505 | 4,667 |
| Other species | | 1,585 | | 4,906 |