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The data on catch and effort of snapper for the South Australian Marine Scalefish fishery were provided by Angelo Tsolos of the Fisheries Statistics Unit of SARDI (Aquatic Sciences). Our gratitude is extended to Don Dew of Adelaide's SAFCOL fish market, who provided the daily market data for snapper around the fishery closure periods in 2004 and 2005. The data-entry for these data was undertaken by Tina Lagana, also of SARDI's Fisheries Statistics Unit.

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1. EXECUTIVE SUMMARY

- In the late 1990s the snapper fishery had recovered from a period of low biomass, and was producing high catches and catch rates. However, in 1998/99 there was a significant drop in longline catch and catch per unit effort in Northern Spencer Gulf, which suggested a reduction in biomass of the large, old fish. This indicated a need for review of the management arrangements for the species. Two potential management options were considered: introduction of a seasonal closure as a means of reducing fishing effort; introduction of a maximum size limit. The potential effectiveness of each option was assessed, which identified the closure as a favourable management strategy. As such, in 2000 seasonal closures were introduced to the management regime of the snapper fishery. From 2000-02, two three-week closures were used per year, i.e. one in August and the second in November. The closures were reviewed in 2003, after which the August closure was discontinued, whilst the November one was extended to include almost the whole month. This regime of November closures was adopted in each year of 2003-05.

- The aim of this report was to provide information relevant to assessing the effectiveness of the closures. Effectiveness would depend on whether the closures reduced fishing effort below the level that it would have been in the absence of closures. Several datasets were extracted from the commercial catch and effort data between 1994 and 2005. For consideration of trends in monthly effort, these 12 years were divided into four triennia, i.e. 1994-96, 1997-99, 2000-02 and 2003-5, which constituted two pre-closure and two closure periods. These triennia also differed with respect to the biomass of snapper available, which affected commercial catch, effort and CPUE estimates. For each region, i.e. Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG) and Gulf St. Vincent (GSV) the temporal trends in monthly effort clearly showed the effects of the fishery closures. There were perceptible reductions in effort relatable to closures in both August and November of 2000-02, and even less effort during November in each of 2003-05. There were reductions in catch associated with these reductions in effort.

- Such evidence for the redistribution of fishing effort does not necessarily mean that annual fishing effort was reduced relative to what it would have been in the absence of closures, as fishers may have increased effort either in October or December. The consideration of patterns of daily fishing effort for the months of October to December

in 1995 to 2005, helped resolve this. These data showed that there was minimal effect of the November closures on the fishing activity during October. However, on the reopening of the fishery there was generally a substantial increase in fishing effort that resulted in high catches. However, these particularly high daily levels of effort and catch generally lasted only several days before declining to moderate levels that were sustained until the pre-Christmas fishing period. As such, the effects of the closures on effort and catch in December appeared to be relatively short-lived.

- The inflated effort during the short period of several days after each closure is unlikely to have negated the reduction in effort attributable to the November closure. As such, the consideration of commercial effort and catch at several time scales strongly suggests that the snapper fishery closures were effective in reducing targeted effort on snapper.

- The levels of reduction in annual fishing effort attributable to the closures were estimated using linear regression. They varied between regions, triennia and gear types. The reductions for handline effort ranged between 2.8 – 11.8% per annum and for longlines from 1.0 to 6.1% per annum.

2. BACKGROUND

In late 1999, SARDI Aquatic Sciences raised concern about the long-term sustainability of the South Australian snapper fishery (McGlennon and Jones 1999). This prompted a detailed consideration of the status of the fishery by PIRSA Fisheries and the Marine Scalefish Fishery Management Committee, and ultimately led to a change in the management arrangements for the fishery. As a result, in 2000 seasonal closures were introduced to the management regime for the first time and have been used in each year since. For the first three years, i.e. 2000 to 2002 two seasonal closures per year were used, each of a three-week duration in August and November. In 2003, these management arrangements were reviewed, resulting in the August closure being dropped, whilst the duration of the November closure was extended to include almost the entire month. This modified closure regime was also used in both 2004 and 2005.

During the review that took place in 2003, it was decided that there would be an assessment of the effectiveness of the month-long, November closure after the three-year trial period of 2003 to 2005. This assessment would determine whether the seasonal closure should be retained in the management program in 2006, and into the future. This report summarises information that is relevant to that assessment process. The following section of this chapter provides a description of the historical context in which the closures were first introduced. It provides a summary of the assessment of the biological status of the snapper populations in 1999, when the need for management action was first raised. It also summarises the discussions and steps that were taken that led to the development and introduction of the seasonal closure regime.

Chapter 3 describes the data that are considered in this report and the methods that were used for their analyses. The results are then presented in Chapter 4, where commercial fishery effort and catch data are presented at both the daily and monthly levels, for a number of years both prior to and subsequent to the introduction of the fishery closures. Such data provide a basis for comparing trends over time, with which to assess the impacts of the fishery closures. Furthermore, daily data on weight of snapper sold and price paid at the SAFCOL fish market are presented for two-month periods both before and after the closures in each of 2004 and 2005.

2.1 Concern for fishery status in 1998/99

In the late 1990s it was apparent that the commercial sector of the Marine Scalefish Fishery was taking the greater share of the snapper catch in South Australia. This was based on the reported catch of the commercial sector and the relatively low estimated catch by the recreational boat sector, as determined by a creel survey that was done from 1994 to 1996 in the Gulf and West Coast waters (McGlennon and Kinloch 1997). At that time the main gear types that were used in the commercial snapper fishery were handlines and longlines, since the use of haul nets for targeting snapper had been prohibited in 1993. Handlines were the dominant gear type across all geographic regions whilst the most significant longline fishery was in northern Spencer Gulf (NSG) between Whyalla, Port Pirie and north of Point Lowly.

In 1998/99 the regional commercial catches of snapper were relatively high, as there was a general State-wide recovery in catch after the poor catches that were attained through the early 1990s (McGlennon and Jones 1999). In that year targeted handline catch and CPUE were the highest that had been recorded in NSG, whilst targeted fishing effort was at its second highest level. In sharp contrast, however, in 1998/99 there was a substantial decline in the longline catch to 33.2 tonnes, the lowest recorded since 1981/82 and only 40% of that of the previous year. Targeted longline CPUE fell by 39% in that year whilst a historic low in targeted longline effort was also recorded.

The significant drop in the longline fishery relative to that of the handline sector caused considerable alarm the status of the stock and its future. At that time, handlines and longlines were strongly size-selective for snapper (McGlennon and Jones 1997). Whilst handlines selectively took small-medium fish in the 4-12 year age classes, longlines predominantly took older, larger fish in the age range of 12-35 years. The snapper population in South Australia experiences considerable variation in year class strength, and fishery catches can be reliant on only one or two strong year classes (McGlennon et al. 2000). This was the case in 1998/99 when the longline fishery was largely dependent on the strong 1979-year class. As such, the observed drop in catch and catch rates suggested a fish-down of the biomass of that year class. It was this apparent reduction in biomass of large, old fish as well as the lack of indications of any strong year classes of younger fish that most concerned the fishery scientists. They considered that the large, old fish were extremely important because they constituted a relatively stable component of the population of this species that experiences cyclical variation in biomass due to highly variable recruitment (McGlennon and Jones 1999). Furthermore, it was reasoned that such fish contribute significantly to egg production, based

on the exponential relationship between fecundity and fish size. It was also reasoned that there was a need to maintain the biomass of such fish to ensure high egg production to thereby maximise the chance of producing a strong year class when the environmental conditions were suitable. Otherwise egg production would rely on the younger fish whose abundance is variable in time and dependent on year class strength. In combination, these factors suggested that from a precautionary perspective there was a need to review the management arrangements for the fishery.

2.2 Discussions of the Snapper Fishery Working Group

In response to the concerns about the steep decline in the longline fishery the Snapper Fishery Working Group was convened in August 1999 by the Marine Scalefish Fishery Management Committee (MSFMC), to assess the significance of the loss of such large, old fish and any possible management responses. The discussions of the group culminated in a discussion paper that was presented to the MSFMC in January 2000 (Shanks 2000). This discussion paper reported that the principle management concern was the possibility of 'recruitment overfishing', i.e. a reduction in reproductive capacity of the population to sustain recruitment. The concern was that such recruitment overfishing could eventuate from:

- the loss of large individuals by commercial longlining;
- the possible redirection of longline to handline fishing effort whose focus on smaller, younger fish could negatively affect the numbers of fish that recruit to the older age classes;
- and the expansion of the recreational fishing sector for which the large, old snapper represent trophy fish, and thereby attract considerable targeted effort.

Therefore, the discussion paper identified that management measures were required to address the potential problem of recruitment overfishing by protecting the larger fish, whilst simultaneously ensuring that sufficient small fish survived to ultimately recruit to the larger size classes. It was also acknowledged that a worse situation existed with the status of the stock in Gulf St. Vincent. In this Gulf, catches had declined considerably since the mid 1980s, and it was thought that recovery of biomass would require drastic management measures and possibly several years of favourable recruitment conditions (Shanks 2000).

The Discussion Paper listed a number of management options that were discussed by the Snapper Fishery Working Group. Some of these options were ultimately formulated into a package of management recommendations. Following is a summary of the discussions by the Working Group with respect to these various management options.

2.2.1 Area and time closures

Fishery closures were considered as a realistic, manageable and practical way for reducing fishing effort in the snapper fishery. A State-wide closure of this fishery was suggested to have a number of likely benefits. It would: protect fish during their spawning migrations; be conclusive and not involve the problem of 'lines on the water' and thus relatively easy to enforce; avoid any problems with effort displacement; and would protect the smaller spawning aggregation of Gulf St. Vincent.

From the perspective of the timing of a closure, it was considered that the longer that it was in place the better for the stock. There was discussion of a closure in November and December, when the fish aggregate for spawning. However, it was considered that a closure through December would be socially unacceptable because of potential impacts on recreational fishing and tourism. As such, it was thought that a State-wide closure through November would be preferable. A further consideration was that a closure in November could result in fishing effort being redistributed to other months, and so the closure should be long enough to counteract such redistribution of effort. An economic benefit for the commercial sector was also considered possible from a November closure, since this was a time when the price paid for the catch was traditionally low, due to the increased supply of the product. By removing supply in November the prices received in subsequent months could be higher.

2.2.2 Maximum Legal Size Limit

The second potential management measure that was considered by the Snapper Fishery Working Group was setting a maximum legal size limit. The aim here was to protect the larger individuals from over-exploitation by commercial and recreational fishers, to enhance egg production and recruitment. Several issues that would be associated with using a maximum size limit were discussed. Firstly, there would likely be incidental mortality associated with longline fishing as some oversized fish would die on the lines prior to them being retrieved. Secondly, the survival of fish released after capture on handlines would depend on their response to the effects of barotrauma and post-release infection. Some members considered that barotrauma could be alleviated, to some extent, by puncturing the swim bladder prior to releasing the fish, whilst infection could be reduced through other appropriate handling practises.

2.2.3 Reduction in hooks available to longliners

At the time of discussions a maximum of 400 hooks could be legally used per longline licence during fishing operations. A proposal was presented that this be reduced to 300 hooks, to reduce the capture rate per boatday of large, old fish. It was also considered that this could

secondarily reduce effort on the large, old fish by causing fishers to redirect their effort from longline to handline operations.

2.2.4 Trip limit

A trip limit was considered as a way of limiting the catch of the commercial sector. However, a number of disadvantages were recognised, which identified this as an inappropriate management measure. A cost of implementing such a regime in a low-value fishery such as the MSF fishery may not be justified. Furthermore, since at that time the larger fish attracted a higher price than medium-sized ones, there would be a significant incentive for higher grading. Furthermore, it was difficult to decide upon an appropriate single trip limit for both handline and longline sectors, in order to reduce catch and effort equitably.

2.2.5 Conclusions and Recommended Management Package

The Discussion Paper was completed with a package of recommendations for the snapper fishery. This proposed management package was:

1. that the South Australian snapper fishery be closed to all fishing through the month of November;
2. that a maximum size limit of 75 cm TL be implemented for both commercial and recreational sectors;
3. that the maximum number of hooks that longline operators use per day be reduced from 400 to 300.

Furthermore, it was argued in the Discussion Paper that each of the different management options would individually reduce fishing effort and thereby have a positive effect on recruitment, but the advantage in implementing the whole package of management measures was that it would limit the possibility that fishers could find alternative ways of maintaining their large catches (Shanks 2000). It was thus argued that the removal of individual management measures from the package would reduce its effectiveness.

2.3 Yield-per-recruit and egg-per-recruit modelling

After the release of the discussion paper prepared by Shanks (2000), SARDI was requested to provide advice with respect to the expected impacts of the two main, proposed, regulatory methods, i.e. the closed season and maximum size limit. These were assessed in an egg-per-recruit and yield-per-recruit analysis (McGarvey and Jones 2000, McGarvey 2004). In this modelling exercise the fishery closure was equated to a reduction in fishing mortality, and different durations of fishery closures were equated to different levels of effort reduction. The effort reductions considered were 10%, 20%, 30% and 40%. Furthermore, the modelling exercise assessed the consequences of setting a maximum size limit at either 750, 800 or 850 mm TL. The model was used to assess the effects of these different strategies on the estimated total catch from the fishery and the annual egg production.

The results of the modelling suggested that implementation of a maximum legal size limit (Lmaxl) would substantially increase egg production, but at the expense of a substantial reduction in both the weight and numbers of fish caught. For example, a maximum size limit of 750 mm TL would increase egg production by 56%, but simultaneously reduce catch by the same amount (Table 2.1). The maximum lengths of 800 and 850 mm TL produced lower estimated reductions in catch, but less increase in egg production. Furthermore, it was also considered that this strategy would disproportionately impact on longline fishers, the charter boat sector and fishing competitions. There was also a possible negative economic effect as effort would be redirected onto the medium-sized fish that have traditionally had lower value because of their poor marketability compared to both small and large fish, thus reducing the value of the landed catch. Overall, these results suggested that the introduction of a maximum size limit would be an unfavourable strategy for the South Australian snapper fishery.

In contrast, the modelling results for reducing fishing mortality (F) by 10 – 40%, thus simulating the impacts of fishery closures of different durations, gave more positive results. The reductions in fishing effort of 10, 20, 30 and 40% increased egg production by 11 to 60% (Table 2.1). Simultaneously, small increases of 1-2% in yield-per-recruit were predicted, despite some reduction in numbers of fish caught. The reductions in fishing mortality shifted the numbers-at-age curve to the right, thus increasing the average age and weight of fish at their time of capture. In summary, the modelling suggested that, based on a range of likely values of F and natural mortality (M), the strategy of reducing F by introducing a fishery

closure would yield significant increases in egg production, whilst providing slight increases in yield by weight. As such, this was considered a favourable management strategy.

Table 2.1. Results from the egg-per-recruit and yield-per-recruit modelling that assessed the consequences for egg production, yield-per-recruit and numbers per recruit of different management strategies. The results are percentage value change from a baseline scenario (McGarvey 2004). Green shading indicates an increase, red shading indicates a reduction compared to the baseline.

	Natural mortality (M)	Fishing mortality (F)	Eggs per recruit (%)	Yield (weight) per recruit (%)	Yield (Nos) per recruit (%)
Lmaxl = 750 mm	0.1	0.15	+56	-56	-29
Lmaxl = 800 mm	0.1	0.15	+36	-39	-17
Lmaxl = 850 mm	0.1	0.15	+29	-32	-14
Lmaxl = 850 mm	0.1	0.165	+16	-31	-10
Reduce F 10%	0.1	0.135	+11	+1	-3
Reduce F 20%	0.1	0.105	+25	+2	-6
Reduce F 30%	0.1	0.105	+40	+2	-11
Reduce F 40%	0.1	0.09	+60	+1	-16

2.4 Implementation of fishery closure regime

It was apparent from the modelling that setting a maximum size limit or implementing fishery closures would each provide approximately equal increases in egg production. However, the maximum size limit would result in a substantial reduction in catch, whilst the closures would result in a modest increase in catch. The latter, therefore, would maintain the economic viability of the fishery. As such, it was decided that a regime of fishery closures would be preferable. Ultimately the decision was made to introduce two three-week closures, one in August and the second in November. The timing of the two closures was determined on the basis of equity, i.e. to ensure that both the longline and handline commercial sectors, as well as the recreational sector, were all impacted by the closures.

3. ANALYTICAL APPROACH TO ASSESSMENT OF CLOSURES

The purpose of this report was to provide information to help assess the effectiveness of the annual regime of the closures of the snapper fishery. Since the closures were aimed at reducing annual fishing effort by approximately 10%, a demonstration of their effectiveness would depend on revealing that some effort reduction had been achieved. Yet providing such a demonstration is not so simple in this multi-species fishery where effort on different species varies according to their relative changes in biomass. As such, there could be considerable inter-annual variation in targeted effort on snapper that was unrelated to the closures. The approach adopted here was that if the closures were effective then fishing effort on snapper would need to be lower than it would have been had there not have been any closures. For this purpose the main data that were considered came from the commercial fishing sector and included monthly and daily data from the commercial catch and effort database. These data were augmented with some from the SAFCOL fish market on weight of snapper and price paid on a daily basis around the time of the closures in 2004 and 2005. The conceptual basis for the different analyses and the methods that were used are described below.

3.1 Consideration of monthly fishing effort and catch

For analysis of the catch and effort data there were several approaches adopted. The first involved an analysis of monthly patterns in fishing catch and effort for the period of 1994 to 2005. This allowed a comparison of trends between the six years prior to implementation of fishery closures and the six years during which closures were used. To achieve this, the data for the 12-year period were divided into four, consecutive, three-year periods, i.e. two, three-year, pre-closure periods of 1994-96 and 1997-99, and two periods of fishery closures of 2000-02 and 2003-05. This was done because the different triennia were characterised by different levels of biomass of snapper available to the fishery (see Section 4.1), whilst the nature of the closures differed between 2000-02 and 2003-05. During the former period there were two three-week closures. In 2000 the two seasonal closures were between the dates of 1st to 20th August and the 6th to 25th November. In 2001, the dates in August were the same as in the previous year, whilst those in November were from the 6th to 26th. In 2002, the closure dates were 1st-20th August and the 6th-26th November. In contrast, for each year from 2003 to 2005 the August closure was dropped whilst the November one was extended to include from midday 1st November until midday 30th November, thus effectively providing two fishing days in November.

For each of the three-year periods of 1994-96, 1997-99, 2000-02, 2003-05, the monthly totals of commercial effort and catch were developed for each month from July to January, from which an average for each calendar month was calculated across the three years. Monthly averages for both effort and catch were calculated for both gear types, i.e. handlines and longlines for each of the three fishery regions of Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG) and Gulf St. Vincent (GSV). For each effort or catch category the monthly averages between July and the following January were plotted so as to describe the 7-month trend for that triennium. These 7-month trends were then compared between the four triennia.

In order to determine whether the patterns of distribution of fishing effort within individual years changed over time, two monthly ratios were calculated for each year, i.e. the handline effort in November to that in October (Nov_{ef}/Oct_{ef}), and the effort in November to that in December (Nov_{ef}/Dec_{ef}). These months were considered, as they have historically constituted the main handline season during which the spawning aggregations were targeted. For the Nov_{ef}/Oct_{ef} ratios the data were compared between triennia using a single factor analysis of variance. Prior to analyses the data were tested for homogeneity of variances using Cochran's test, whilst *a posteriori* comparisons amongst means were done using the LSD (least significant difference) method. The average ratios were then calculated across years for each triennium and plotted against the four consecutive time periods. A similar analysis was also done for the Nov_{ef}/Dec_{ef} effort ratios. Furthermore, similar ratios were calculated for fishery catches, i.e. Nov_{ct}/Oct_{ct} and Nov_{ct}/Dec_{ct}. These data were also compared amongst triennia using single factor analyses of variance and the results were presented as averages of the ratios ($\pm$SD).

3.2 Consideration of daily catch and effort data

The second type of analysis of commercial catch and effort data involved consideration of selected data at a daily level. Since July 2003 it has been compulsory for commercial fishers to provide their catch and effort information at a daily level, submitted through their monthly catch returns. Before this time, however, many fishers had already been providing their catch and effort information at a daily level despite that the minimum requirement was for them to provide monthly totals of catch and effort. Thus, for the years prior to 2003 there exists within the commercial fishery database an historic record of daily catch and effort information, which provides the opportunity for analysis of fishing trends and fisher behaviour at the daily level.

In this study, all commercial catch and effort data for snapper that were provided at the daily level for the months of October, November and December in each year from 1995 to 2005 were extracted from the database. For the handline fisheries in each of NSG, SSG and GSV these daily catch and effort data were graphed against consecutive days to display the patterns of variation over time. This was done independently for each year from 1995 to 2005, which allowed consideration of each within-year pattern in fishing trends, and comparison of trends between years, including the pre-closure period of 1995-99 and the closure years of 2000 to 2005.

3.3 SAFCOL market – auction volumes and average price

To augment the data from the commercial fishers some data also relating to the commercial snapper fishery were obtained from the SAFCOL fish market in Adelaide. These data were for the weight and price per kg for snapper that were auctioned at the SAFCOL fish market through two-month periods both before and after the November closures in each of 2004 and 2005. Data were obtained for every sales transaction that involved snapper, including the weight sold and the price paid, for every day throughout these two-month periods. These data were then used to calculate the total weight of snapper sold per day in that market, as well as the average price paid per kg. These were graphed against day of the year to present a time-series to elucidate the trends over time.

4. RESULTS

4.1 Annual variation in catch statistics

In this study the effects of the snapper fishery closures were assessed by consideration of the commercial catch and effort data for the 12-year period of 1994 to 2005. During this period the reported, State-wide, total commercial catch of snapper increased in each year from its lowest recorded level in 1994 to the record catch that was taken in 2001, a more than 2.5 fold increase (Fig. 4.1a). The annual, total, State-wide, fishing effort demonstrated a different pattern of variation, being relatively high between 1994-96, dropping in 1997-99, increasing again in 2000-02, and subsequently dropping again during the last triennium (Fig. 4.1b). Because of these different temporal trends in total catch and effort, CPUE increased consistently between 1994 and 2001, and subsequently varied around a high level (Fig. 4.1b).

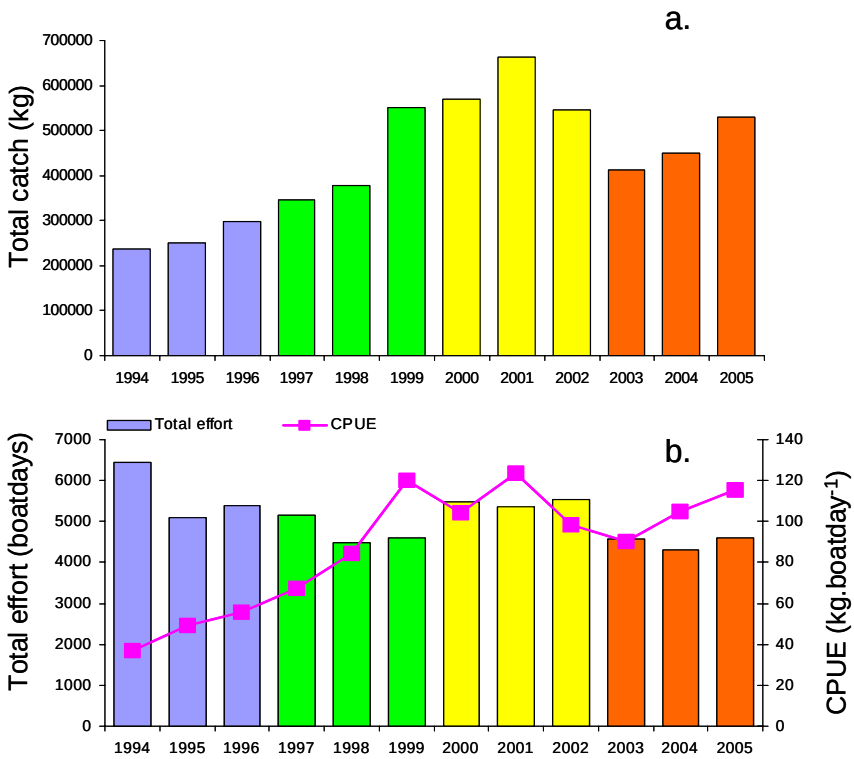

Fig. 4.1 a. Total State-wide commercial catch of snapper from 1994 to 2005. b. Annual estimates of total commercial fishing effort and CPUE by year. Different coloured bars indicate the four different triennia that were considered in the analyses.

The estimates of catch and CPUE strongly indicate that through the 12-year period of 1994 to 2005, there was substantial variation in the fishable biomass of snapper in South Australian waters. This finding is supported by a time series of estimated biomass for each of the three main fishery regions, as determined by the computer fishery model 'SnapEst' that was reported in the last stock assessment report (Fowler et al. 2005). The regional increases in biomass through the 1990s were related to the recruitment of the strong 1991-year class to the population. This year class has subsequently sustained all regional fisheries of the State for approximately 10 years (Fowler et al. 2005).

The focus of this report is to provide information to help assess the effectiveness of the fishery closures that have been implemented on an annual basis since 2000. Such an assessment must recognise the radical changes in biomass and structure that the snapper population experienced over the past decade. In the following section the monthly trends in catch and effort are considered for the past 12 years. This period was divided into four three-year periods. The first of these, i.e. the triennium of 1994-96 was characterised by low fishable biomass of snapper and no fishery closures (Fig. 4.1). The following triennium of 1997-99 was a period of increasing biomass, during which there were no fishery closures. For 2000-02, there were two closures each of three weeks duration, whilst record catches and CPUE indicate that biomass peaked at this time. In the final three-year period of 2003-05, the August closure was dropped but the November one was extended in duration from midday 1st to midday 30th November. Furthermore, the catches suggest that biomass was marginally lower than in the previous triennium.

4.2 Consideration of monthly and triennial fishing effort and catch

4.2.1 NSG - handline

In the handline fishery in NSG during the triennium of 1994-96 there was a distinct pattern in the average monthly effort (Fig. 4.2a). Handline effort was low in July, but increased consistently over the subsequent months before it peaked in December, and then fell marginally in January. Such increasing effort is likely to have been related to fishers targeting spawning aggregations through the reproductive season. During this triennium the average handline catch was low, but nevertheless demonstrated a marginal increase from month to month between July and December in response to the increasing effort (Fig. 4.2c).

In the second triennium, i.e. 1997-99, the pattern of targeted handline effort on snapper was similar to that of the previous one, except for higher levels of effort that were observed in all months except October, whilst there was a more substantial drop in effort between December

and January (Fig. 4.2a). These higher effort levels contributed to higher average monthly catches, compared with the previous triennium (Fig. 4.2c).

For 2000-02, the average fishing effort in July was relatively high compared to the two previous three-year periods (Fig. 4.2b). It then dropped in August due to the closure, before increasing again in September. It dropped again in November as a result of the second closure, before subsequently increasing to a peak in December to the highest recorded average of 250 boatdays.month^{-1}. The average monthly catches in each of August and November were relatively lower than those during the pre-closure period, but nevertheless did increase marginally in November before the substantial increase of December (Fig. 4.2d).

During the final triennium of 2003-05 the variation in the monthly pattern in handline effort was similar to that of the previous period except that handline effort was generally much lower (Fig. 4.2b). The monthly effort was approximately similar between July and October, but decreased to near zero in November. Effort then increased dramatically in December, but to a level well below that of 2000-02. The low amounts of effort relate to fishing that occurred either on the 1st of November prior to midday or on the 30th of the month after midday. The average catches in each of July, August, September, October and November were low and approximately equal, before they increased substantially in December (Fig. 4.2d). Thus, during this triennium the November catch was low relative to that from each of the previous three-year periods.

4.2.2 NSG – longline

In each of 1994-96 and 1997-99 longline fishing effort in NSG was relatively high from July to October but fell in November and again in December (Fig. 4.3a). The level of longline fishing effort was much lower in 2000-02, but nevertheless the closures in both August and November resulted in perceptible reductions in fishing effort (Fig. 4.3b). The level of longline fishing effort in 2003-05 was the lowest for the 12-year period because of longline fishers leaving the industry. However, despite this lower effort it was still apparent that the November closure was effective in reducing monthly effort to a negligible level.

The patterns of variation in monthly catch for each three-year period reflect the respective trends in fishing effort. For the two pre-closure periods the average catch fell between September and January (Fig. 4.3c). For 2000-02 longline catch was highest in October, fell to negligible levels in both August and November and then increased marginally in December (Fig. 4.3d). Longline catch in NSG was even lower through 2003-05 except for the month of August, which was not closed to fishing activity.

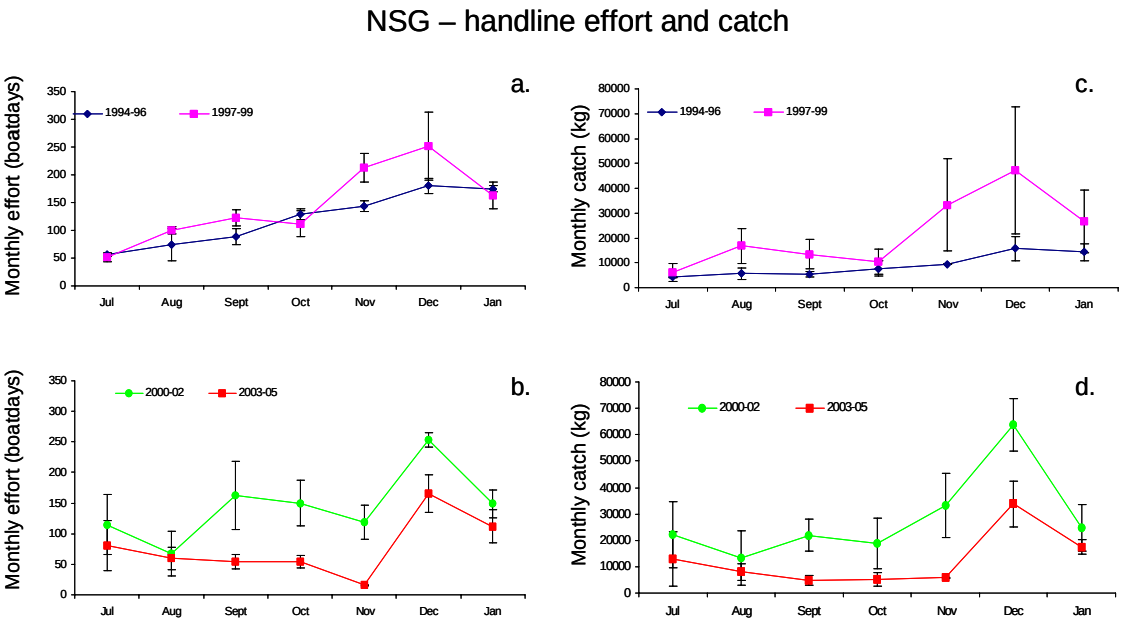

Fig. 4.2 a. Monthly handline fishing effort targeted on snapper in NSG, averaged across the indicated pre-closure, three-year periods. b. Monthly handline fishing effort targeted on snapper, averaged across the three-year periods during which snapper closures were implemented. c. Monthly handline targeted catch of snapper, averaged across the indicated, pre-closure, three-year periods. d. Monthly handline targeted catch of snapper, averaged across three-year periods during which snapper closures were implemented.

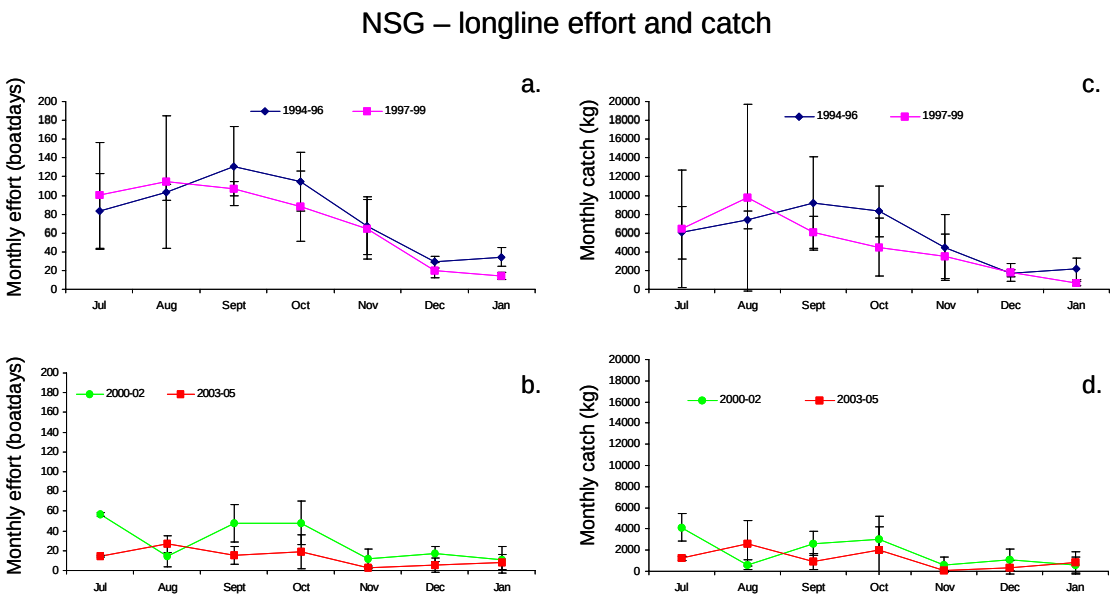

Fig. 4.3 a. Monthly longline fishing effort targeted on snapper in NSG, averaged across the indicated pre-closure, three-year periods. b. Monthly longline fishing effort targeted on snapper, averaged across the three-year periods during which snapper closures were implemented. c. Monthly longline targeted catch of snapper, averaged across the indicated, pre-closure, three-year periods. d. Monthly longline targeted catch of snapper, averaged across three-year periods during which snapper closures were implemented.

4.2.3 SSG - handline

Handline fishing effort demonstrated a consistent pattern of variation through the first two three-year periods. Effort was low from July to October but then rose significantly in November and again through December (Fig. 4.4a). In 2000-02, the level of handline effort was considerably higher than previously, but nevertheless conformed to a similar pattern of increase through November and December (Fig.4.4b). In the three years of 2003-05 the pattern was similar except that fishing effort in November was reduced to a negligible level.

In the pre-closure years of 1994-96, average monthly handline catch was low, but increased marginally through December and January (Fig. 4.4c). In 1997-99 monthly handline catch was low from July until October but increased very substantially in both November and December. In 2000-02 the November catch was substantially less than that of December, whilst in 2003-05 the November catch was very low compared with the peak catch in December (Fig. 4.4d).

4.2.4 SSG – longline

The monthly longline effort in 1994-96 was low from July to October but increased in November before decreasing in December and January (Fig. 4.5a). In the following period of 1997-99 longline effort fell between September and January, but in November was still relatively high. In 2000-02 effort dipped in August, but dropped much more dramatically in November, with only marginal increases in December and January (Fig. 4.5b). In 2003-05 the general level of effort was higher than in the previous three years. It was highest from July to October before falling to a negligible level in November and then increasing again in December.

The average monthly longline catches were poor for both 1994-96 and 1997-99, reflecting both the low effort level and low biomass of fish (Fig. 4.5c). In the first closure period, catch reflected effort and so was low in August and then in November, December and January (Fig. 4.5d). Alternatively, in 2003-05 the August catch was relatively high, whilst that from November was negligible.

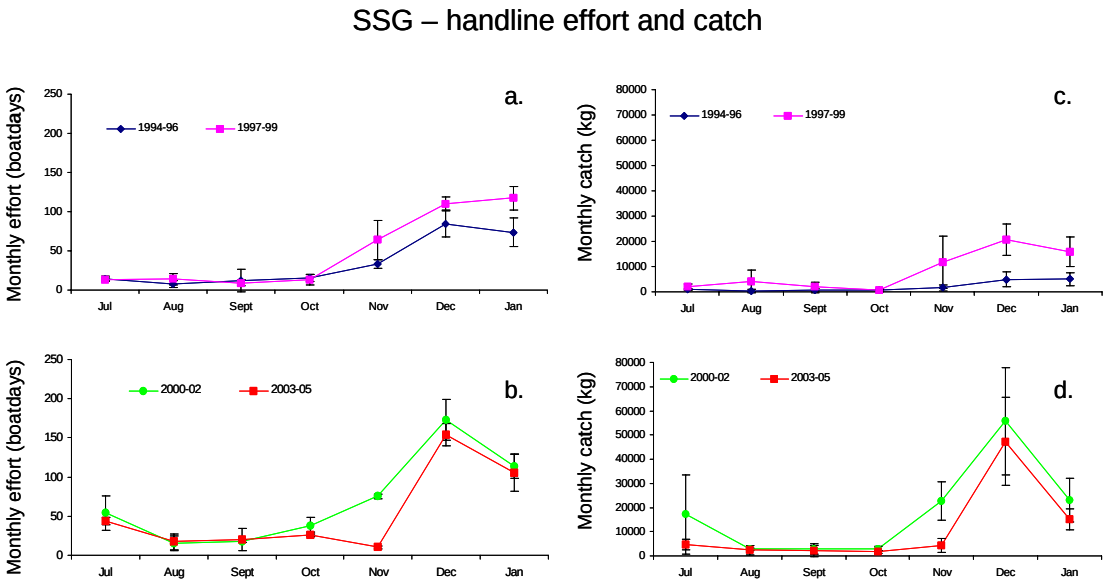

Fig. 4.4 a. Monthly handline fishing effort targeted on snapper in SSG, averaged across the indicated pre-closure, three-year periods. b. Monthly handline fishing effort targeted on snapper, averaged across the three-year periods during which snapper closures were implemented. c. Monthly handline targeted catch of snapper, averaged across the indicated, pre-closure, three-year periods. d. Monthly handline targeted catch of snapper, averaged across three-year periods during which snapper closures were implemented.

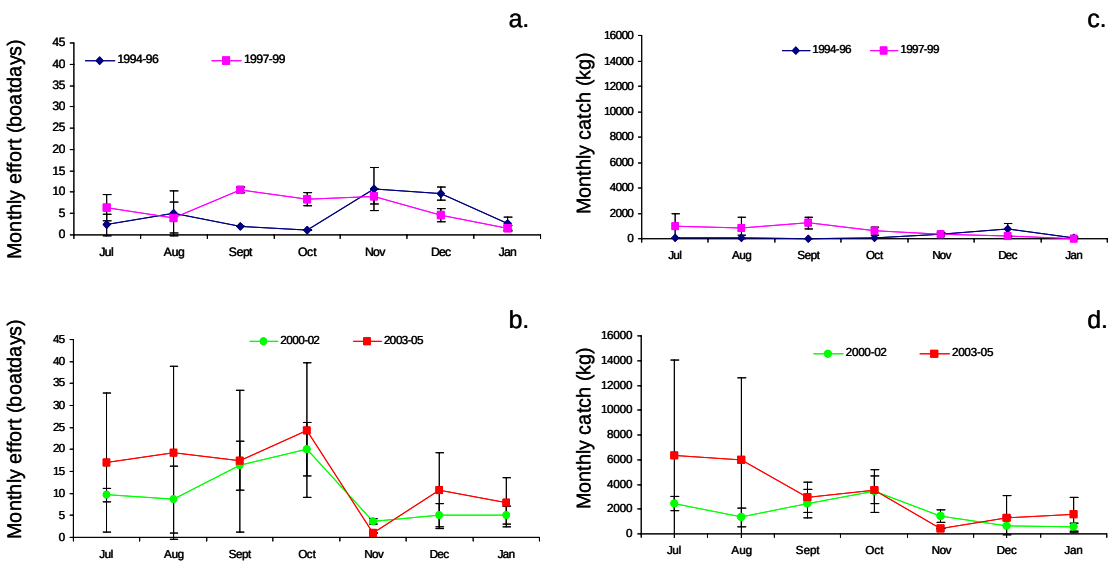

Fig. 4.5 a. Monthly longline fishing effort targeted on snapper in SSG, averaged across the indicated pre-closure, three-year periods. b. Monthly longline fishing effort targeted on snapper, averaged across the three-year periods during which snapper closures were implemented. c. Monthly longline targeted catch of snapper, averaged across the indicated, pre-closure, three-year periods. d. Monthly longline targeted catch of snapper, averaged across three-year periods during which snapper closures were implemented.

4.2.5 GSV – handline

During the first triennium of 1994-96 handline effort was relatively low from July to September, but then increased considerably through each of October, November and marginally so in December (Fig. 4.6a). The pattern was similar for the period of 1997-99, although the increases in November and December were higher. In 2000-02 the pattern of variation was again similar except that the levels of effort in each of August and November were relatively low compared with those of the previous triennia (Fig. 4.6b). The increasing effort was also evident in 2003-05 except for the negligible fishing effort in November.

In 1994-96 the average monthly catches were generally very low, but increased marginally through November, December and January (Fig. 4.6c). In the following triennium, monthly catches were similar from July to October, but were substantially higher in November and December than during the previous triennium. During the first closure period of 2000-02 the pattern of variation in monthly catch was very similar to that of 1997-99, with marginally lower catches in August and November being evident (Fig. 4.6d). Finally, in 2003-05 the pattern of month-to-month variation was similar except that the catch in November was reduced to a negligible level.

4.2.6 GSV – longline

In 1994-96 longline effort was higher in November, December and January than the previous months (Fig. 4.7a). Longline effort was lower during 1997-99 with minimal variation from month-to-month, except for a perceptible increase in November. In the following triennium of 2000-02 the longline effort was generally low but was perceptibly lower in both August and November than the two previous periods (Fig. 4.7b). During 2003-05, longline effort was marginally higher than the previous periods, particularly through August to October. But it then decreased considerably in November before increasing again in December and January.

Longline catch was low through 1994-96, showing an increase only in December and January (Fig. 4.7c). In the following triennium, the highest monthly catches were made in both August and December. Through 2000-02 the catch largely reflected the variation in effort, which was particularly low in August (Fig. 4.7d). The catch in 2003-05 also varied according to effort, increased from July to October, decreased to a negligible level in November and increased again in each of December and January.

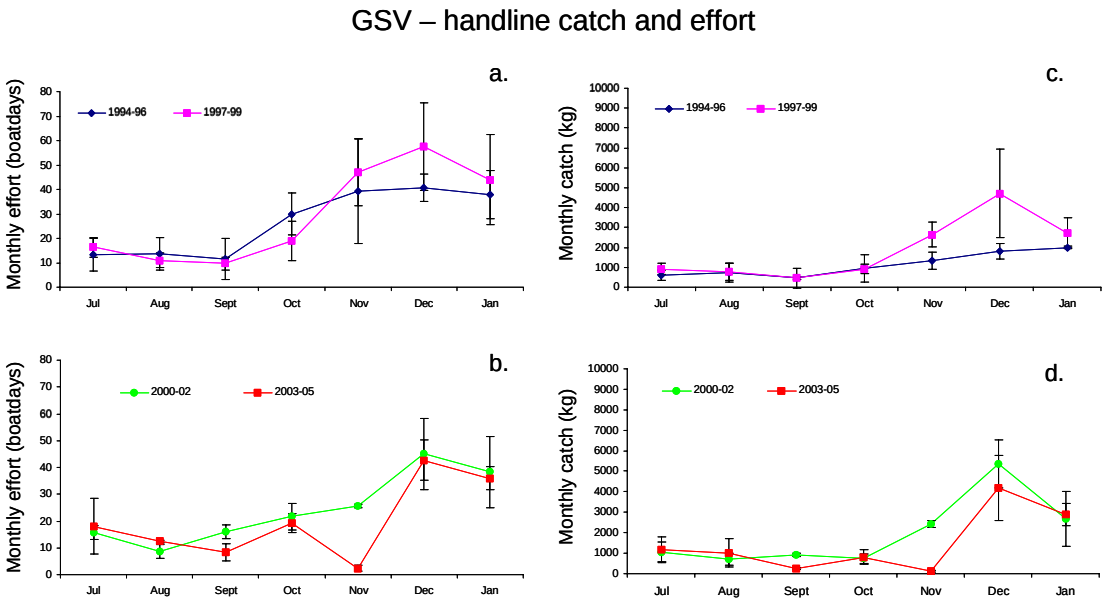

Fig. 4.6 a. Monthly handline fishing effort targeted on snapper in GSV, averaged across the indicated pre-closure, three-year periods. b. Monthly handline fishing effort targeted on snapper, averaged across the three-year periods during which snapper closures were implemented. c. Monthly handline targeted catch of snapper, averaged across the indicated, pre-closure, three-year periods. d. Monthly handline targeted catch of snapper, averaged across three-year periods during which snapper closures were implemented.

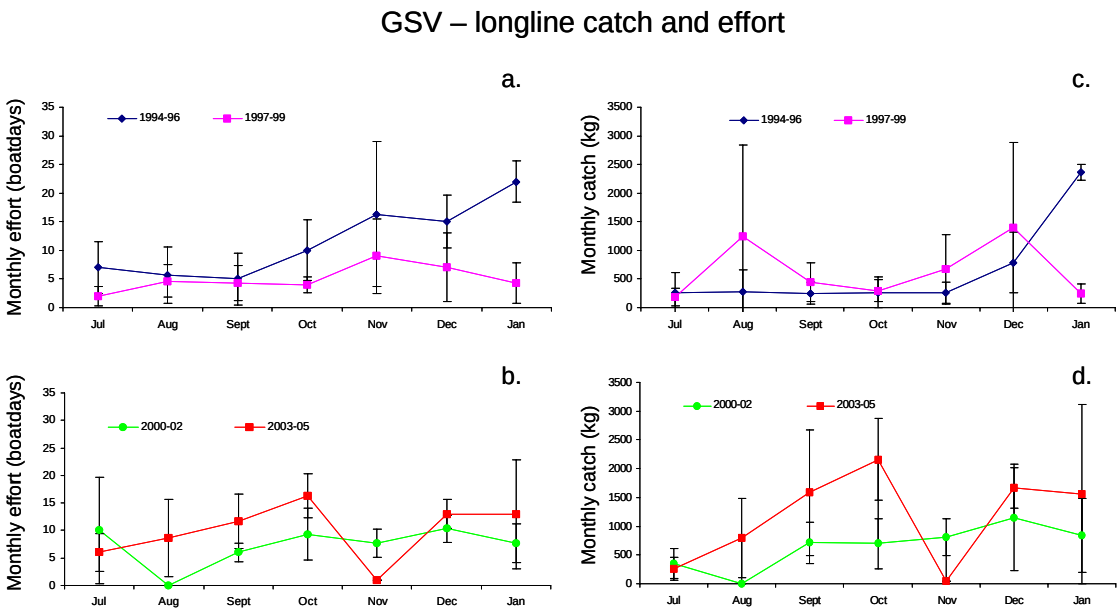

Fig. 4.7 a. Monthly longline fishing effort targeted on snapper in GSV, averaged across the indicated pre-closure, three-year periods. b. Monthly longline fishing effort targeted on snapper, averaged across the three-year periods during which snapper closures were implemented. c. Monthly longline targeted catch of snapper, averaged across the indicated, pre-closure, three-year periods. d. Monthly longline targeted catch of snapper, averaged across three-year periods during which snapper closures were implemented.

4.3 Relative handline effort and catch during October, November, December

The ratios of handline fishing effort and catch in November to both October and December of the same year were calculated for each of the 12 years of 1994 to 2005. Both ratios, i.e. Nov_{ef}/Oct_{ef} and Nov_{ef}/Dec_{ef} were then compared between the four triennia using single factor analyses of variance.

For NSG there were significant differences apparent in both the Nov_{ef}/Oct_{ef} and Nov_{ef}/Dec_{ef} ratios for handline fishing effort between the four triennia (Fig. 4.8a,d). Furthermore, the differences were apparent for the other two regions (Fig. 4.8). This indicates that there was a consistent significant change between the triennia in the way that fishing effort was expended throughout the months of October, November and December. In 1994-96 in each region, Nov_{ef}/Oct_{ef} was marginally above 1, indicating that slightly higher effort in November than October. During the following triennium of 1997-99 there were significant increases in Nov_{ef}/Oct_{ef} for each region, reflecting that during this period of high biomass of snapper there was a relative increase in fishing effort in November. However, in the following two triennia, i.e. 2000-02 and 2003-05, during which there were November closures, there were significant reductions in Nov_{ef}/Oct_{ef} for handline effort. The lowest ratios were obtained for the latter triennium, which reflects the minimal opportunity for fishing through November.

The patterns for Nov_{ef}/Dec_{ef} for handline effort were also relatively consistent between the regions (Fig. 4.8d,e,f). For SSG and GSV the ratios were similar through the first three triennia, indicating a consistent distribution of effort between November and December. For NSG there was a significant reduction in the ratio in 2000-02 that was associated with the first closure. Nevertheless, in all three regions there were significant drops in the ratio during 2003-05 that related to a substantial drop in fishing effort during November.

The differential patterns in fishing effort clearly affected the monthly handline catches of snapper, as is manifested in the monthly ratios (Fig. 4.9). In each region the Nov_{ct}/Oct_{ct} ratios were greater in both 1997-99 and 2000-02 than they were in 2003-05, reflecting the limited opportunity to capture snapper during November of this last triennium. There was a similar decrease in the Nov_{ct}/Dec_{ct} ratios in each region in 2003/05. As such, the closures, particularly that of the last triennium, clearly resulted in a redistribution of the timing of when catches of snapper were made.

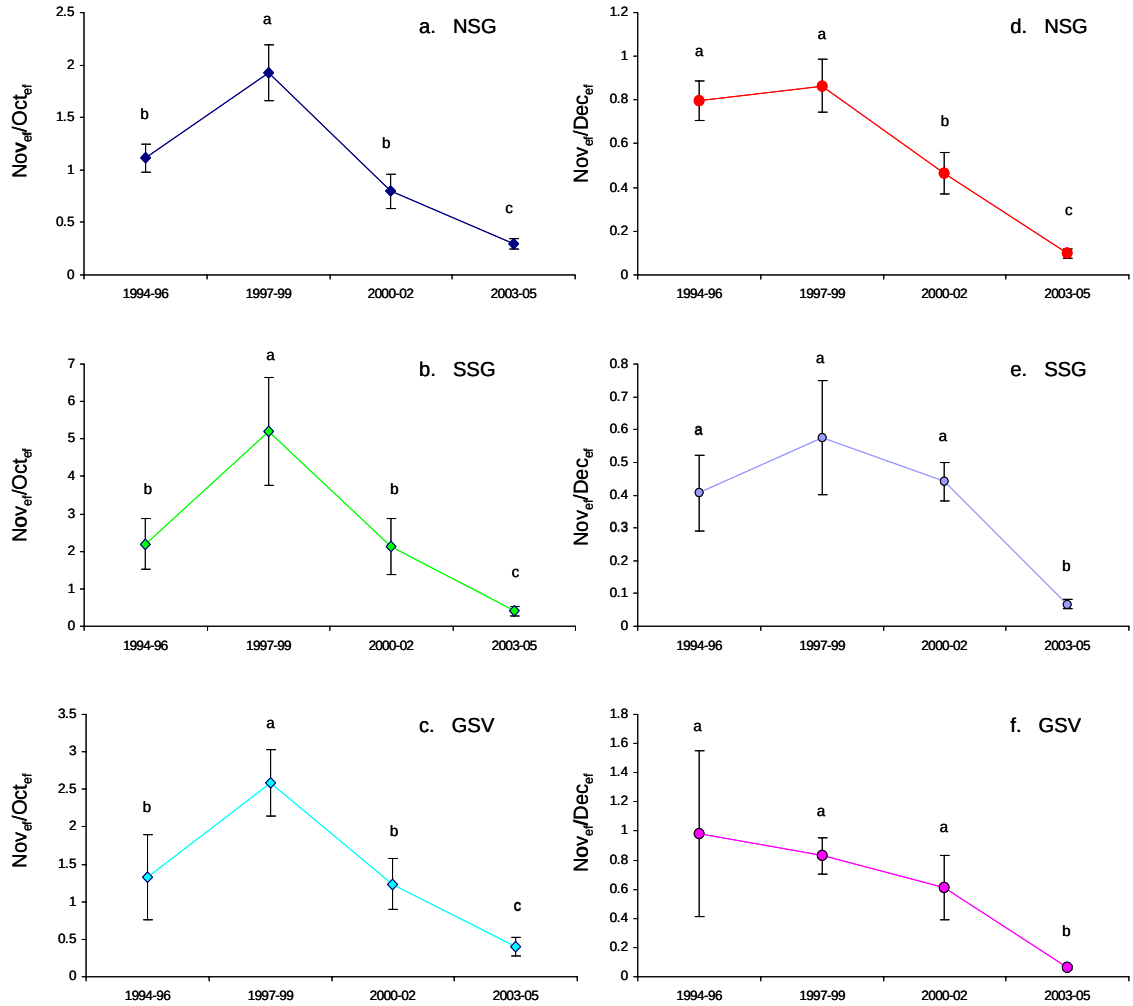

Fig. 4.8 a. Ratio of targeted handline fishing effort between November and October in NSG, averaged across the three years of each triennium (+SD). b. same ratio for SSG. c. same ratio for GSV. d. Ratio of targeted handline fishing effort between November and December in NSG, averaged across the three years of each triennium (+SD). b. same ratio for SSG. c. same ratio for GSV.

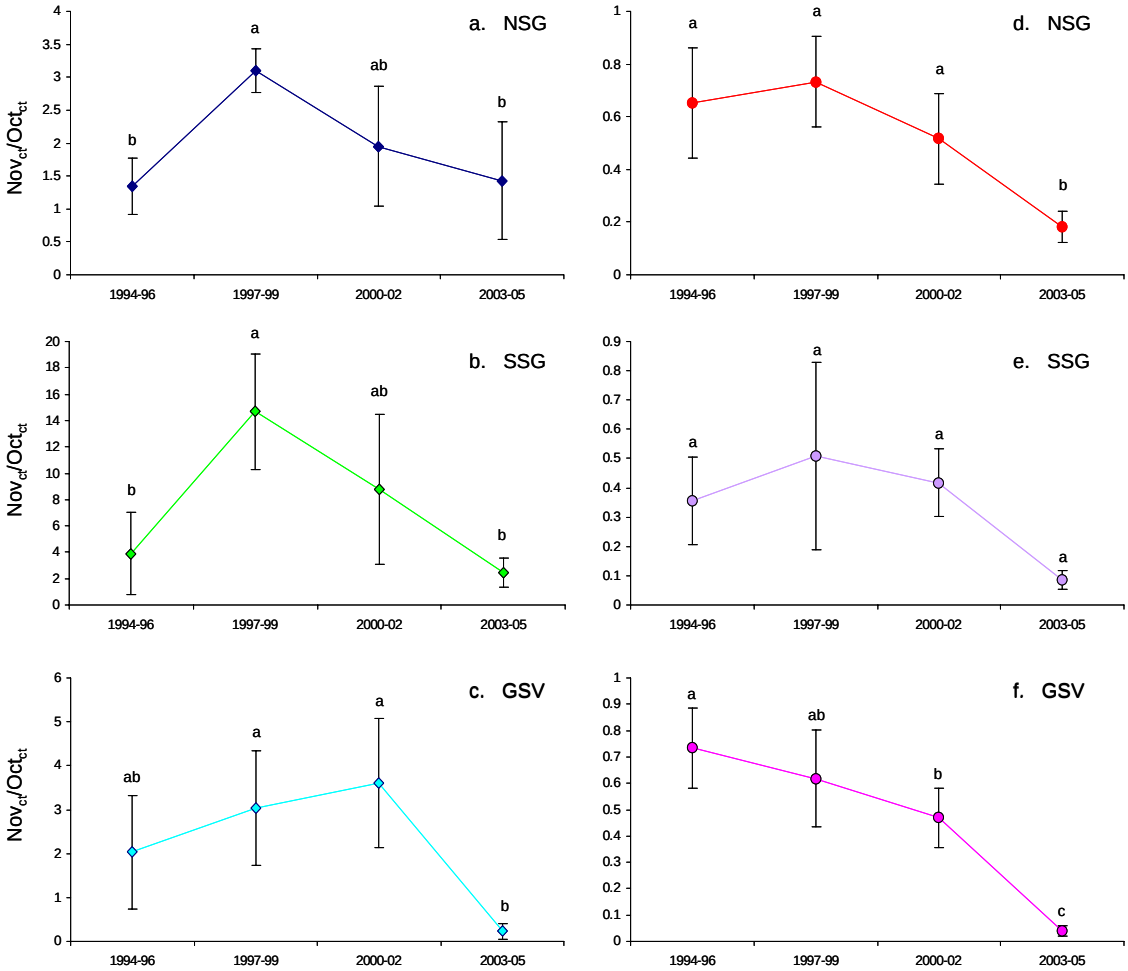

Fig. 4.9 a. Ratio of targeted handline fishing catch between November and October in NSG, averaged across the three years of each triennium (+SD). b. same ratio for SSG. c. same ratio for GSV. d. Ratio of targeted handline fishing catch between November and December in NSG, averaged across the three years of each triennium (+SD). b. same ratio for SSG. c. same ratio for GSV.

4.4 Analysis of daily commercial fishing effort and catch

4.4.1 NSG – handline

A finer scale analysis of fishing effort was achieved by consideration of the pattern of total daily reported fishing effort for the region. In NSG in each year between 1995 and 1999 there was a gradual increase in the reported daily effort between October and December (Fig. 4.10). The graphs for the years of 2000 to 2002 clearly display the zero effort that related to the fishery closures through each November. Furthermore, these closure periods clearly separate the pre- and post-closure periods that demonstrate different levels of effort. Pre-closure effort was generally <5 boatdays.day^{-1}, but occasionally exceeded 10 boatdays.day^{-1}. However, immediately after the reopening of the fishery there was a substantial increase in fishing effort, to 13, 19 and 24 boatdays.day^{-1} in each of 2000, 2001 and 2002, respectively. In 2000 and 2001 the high level of fishing effort was sustained for several weeks, but in 2002 it dropped after several days to <15 boatdays.day^{-1}. Effort then gradually decreased over the following weeks.

In each of 2003, 2004 and 2005 the November closure clearly separated the pre- and post-closure periods that were characterised by different levels of fishing activity (Fig. 4.10). Total effort per day in October was generally <5 boatdays.day^{-1}. However, after the closure there was a dramatic increase to a maximum of around 15 boatdays.day^{-1}, which was sustained for several days. After 3 – 4 days the effort decreased to <10 boatdays.day^{-1} that was then sustained for the remainder of December.

The daily catches through October to December of 1995 to 1999 were low, but gradually increased within each year, thus providing higher catches in December (Fig. 4.11). Furthermore, the pattern of daily reported catch increased between years, such that by 1999 catches of >2,000 kg.d^{-1} were relatively common, with an occasional catch of 4,000 kg.d^{-1}. In 2000 a similar pattern to that through the 1990s was evident except for the zero catches through the closure period of 6-26th November. In both 2001 and 2002 the October catches were generally less than 2,000 kg.d^{-1}, which dropped to zero through the closure period. The reopening of the fishery was associated with a dramatically high catch rate of >11,000 kg.d^{-1} in both years. These high catches lasted for only 1 – 2 days before dropping to <6,000 kg.d^{-1} that were then sustained for several weeks before falling again in the last week of the month.

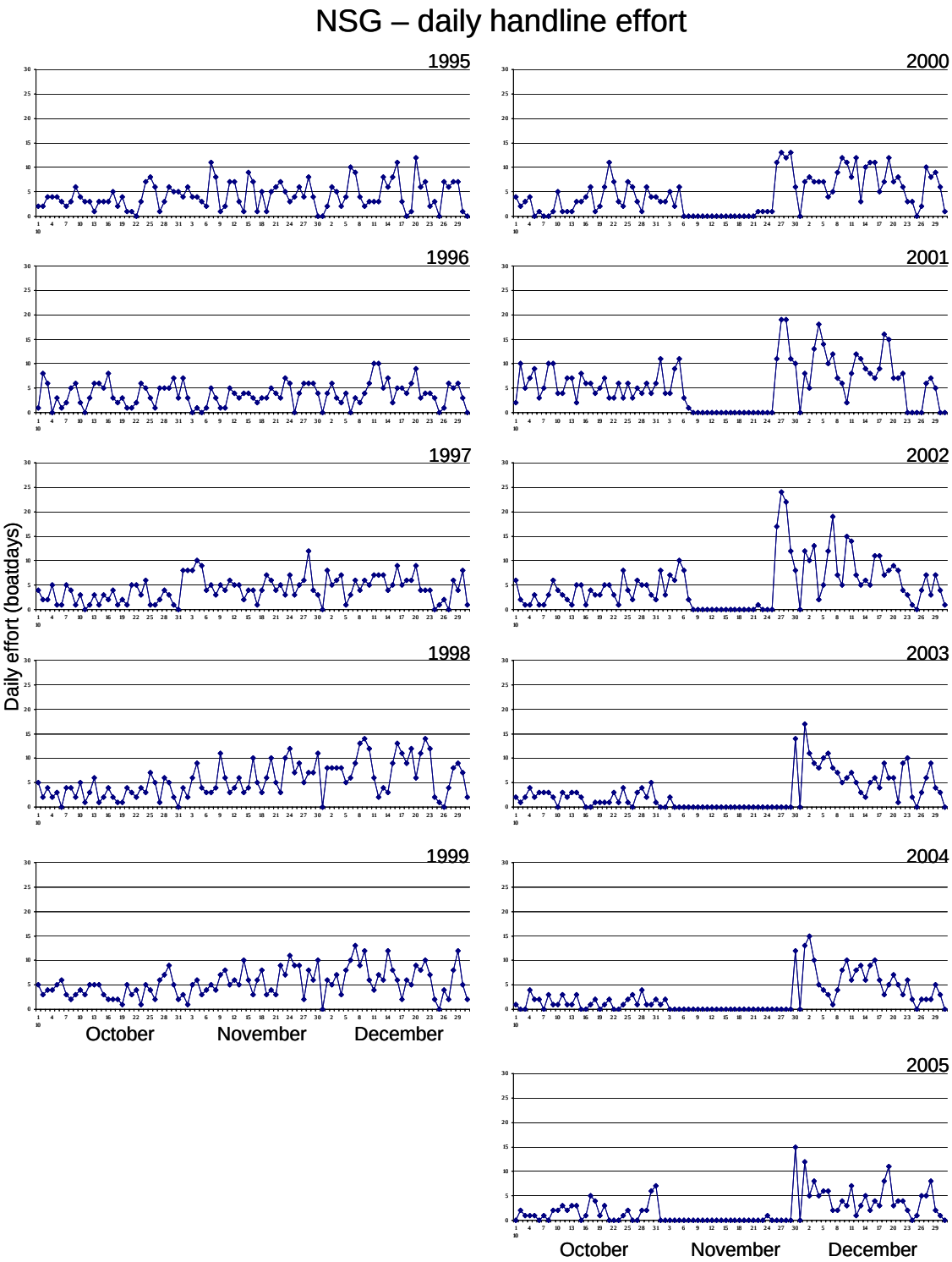

Fig. 4.10. Daily reported handline fishing effort on snapper in NSG for the three month period of October to December of every year from 1995 to 2005.

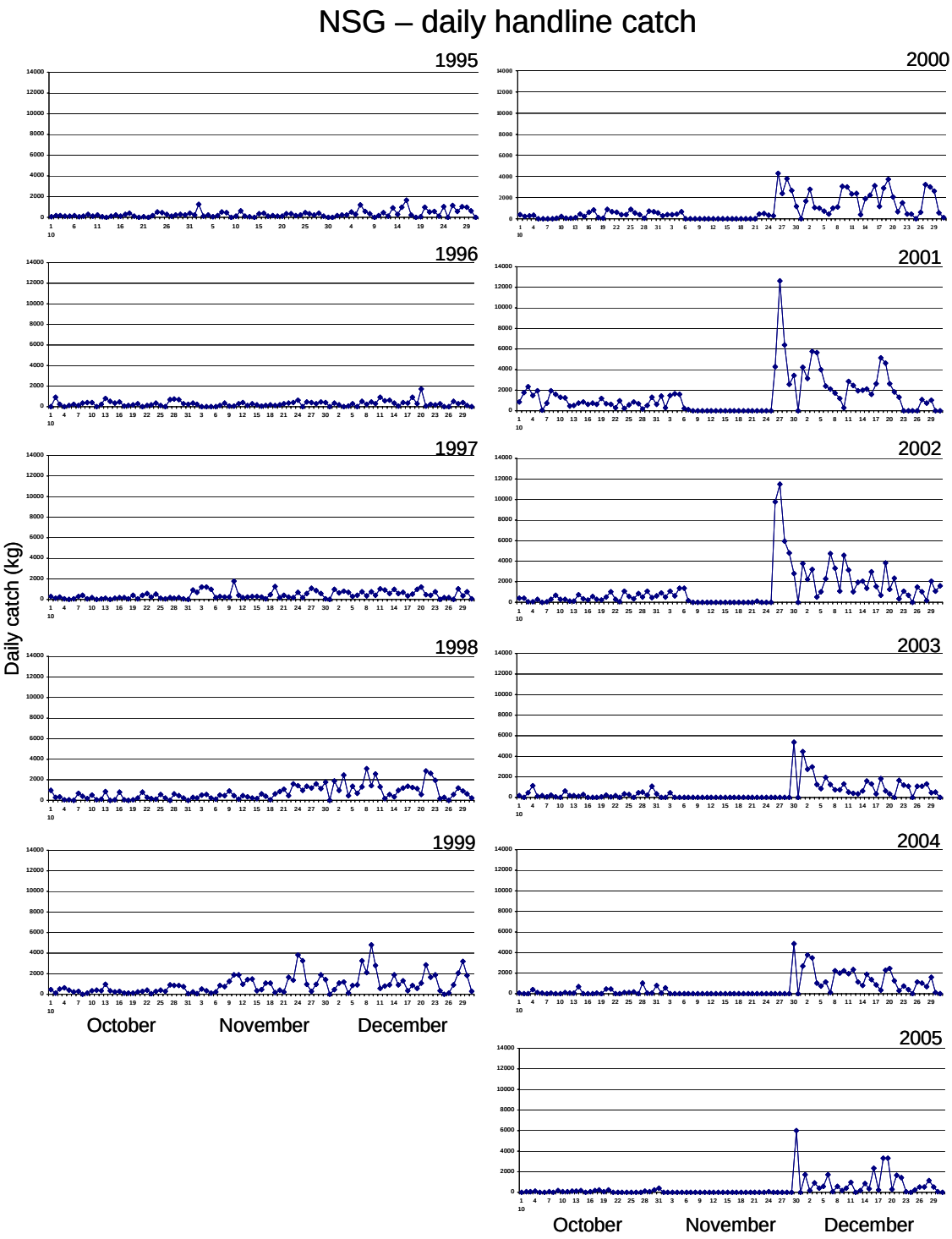

Fig. 4.11. Daily reported fishing catch of snapper in NSG for the three month period of October to December for every year from 1995 to 2005.

The daily catches through October 2003, 2004 and 2005 were very low and generally <500 kg.d^{-1} (Fig. 4.11). They fell to zero through the November closure. The catch of the first day of the reopening of the fishery was >5,000 kg, which was also the highest daily catch over the 3-month period. In each of 2003 and 2004 catches of >2,500 kg.d^{-1} were sustained for a further three days before dropping again to a lower level that was sustained for the remainder of December. In 2005, there was a small peak in catch in the middle of the month, but the sustained levels for the remainder of the month were generally less than 2,000 kg.d^{-1}.

4.4.2 SSG - handline

From 1995 to 1999 the daily reported effort in October was generally 0 – 2 boatdays.day^{-1} (Fig. 4.12). This increased marginally through November before attaining the higher level of 6 – 8 boatdays.day^{-1} in December. A similar pattern was evident in 2000 except for the period of zero effort through November. In 2001 and 2002 the levels of sustained handline effort through late November and December were 8 – 10 boatdays.d^{-1}. In each year of 2003 to 2005 fishing effort was low prior to the closure period, but increased dramatically subsequent to the closure and was sustained at a high level for most of December. In 2003 and 2004, effort decreased considerably in the last week of the month.

In 1995 to 1999 two trends were evident in the daily record of catch (Fig. 4.13). In each year catch was negligible through October, but then gradually increased in either November or December. Furthermore, the extent of the increase in catch changed, i.e. it increased in the later years. By 1999, daily catches of 2,000 kg.d^{-1} were common through late November and December.

During 2000 to 2002 the October catches were again negligible (Fig. 4.13). In early November 2001 there were substantial catches of 2,000 kg.d^{-1} prior to the closure, which then dropped to zero during the closure. On the reopening of the fishery catch rates increased substantially up to 4,000 kg.d^{-1}. These higher catches were sustained for several weeks before dropping a week or so before the end of the month. The sustained level of catch in 2002 was substantially less than that of the two previous years. For 2003 to 2005 the catches in October were negligible, and zero through the November closures. The highest catches of up to >6,000 kg.d^{-1} were achieved immediately after the reopening of the fishery. The high catches were sustained for several weeks before they decreased in the last week of the month.

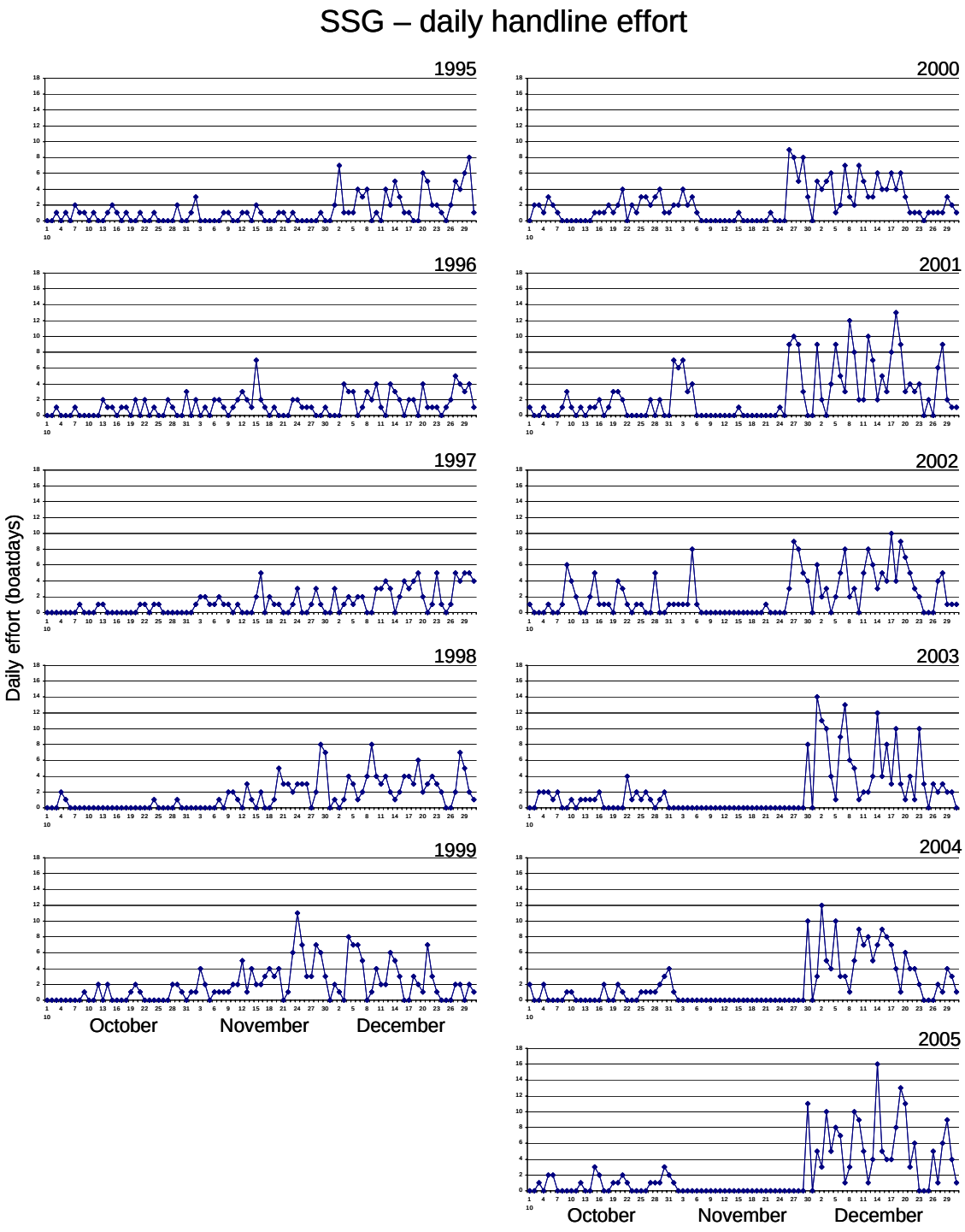

Fig. 4.12. Daily reported fishing effort on snapper in SSG for the three month period of October to December for every year from 1995 to 2005.

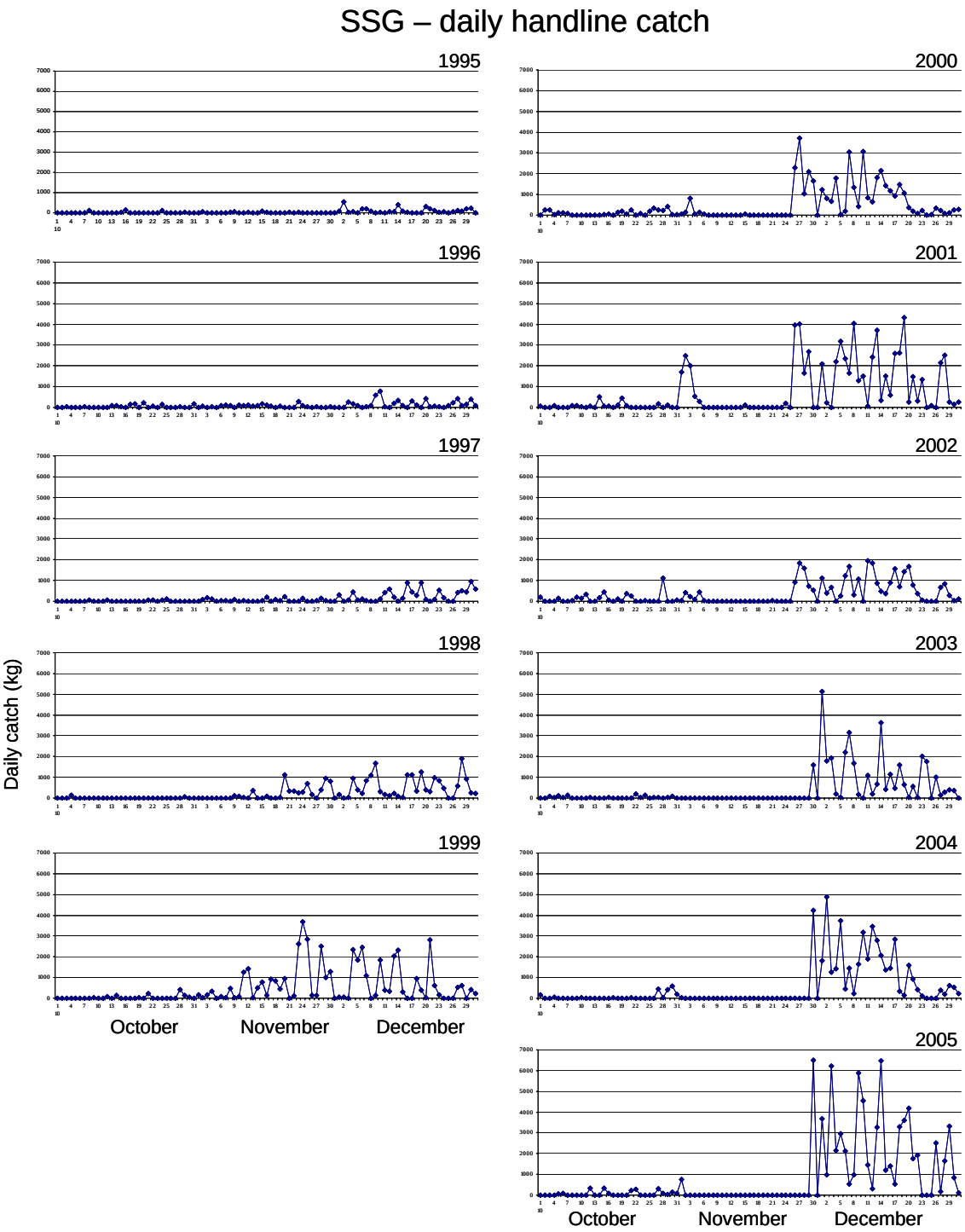

Fig. 4.13. Daily reported fishing catch of snapper in SSG for the three month period of October to December for every year from 1995 to 2005.

4.4.3 GSV - handline

Handline effort was low and regular through the years of 1995 to 1999 (Fig. 4.14). In some years there was a perceptible increase in effort through November and December. Furthermore, there was a general increase in effort between years. Between 2000 and 2005, the pre- and post-closure periods were evident. Pre-closure effort generally varied between 0 - 3 boatdays.day^{-1}. The post-closure period was generally characterised by marginally higher levels of effort, with the highest of 7 boatdays.day^{-1} attained immediately after the closure in 2002. Usually there was no significant peak in effort immediately after the closure.

Through 1995-97 the daily reported catches in GSV rarely exceeded 200 kg.d^{-1} (Fig. 4.15). Such catches became more common through November and December of each of 1998 and 1999. Daily catches were generally low prior to the closure in each year from 2000 to 2005, but were always higher through late November and December after each closure. In both 2000 and 2002 there was a peak in the post-closure catches, which declined after only a few days. The catches generally declined back to low levels by the end of December.

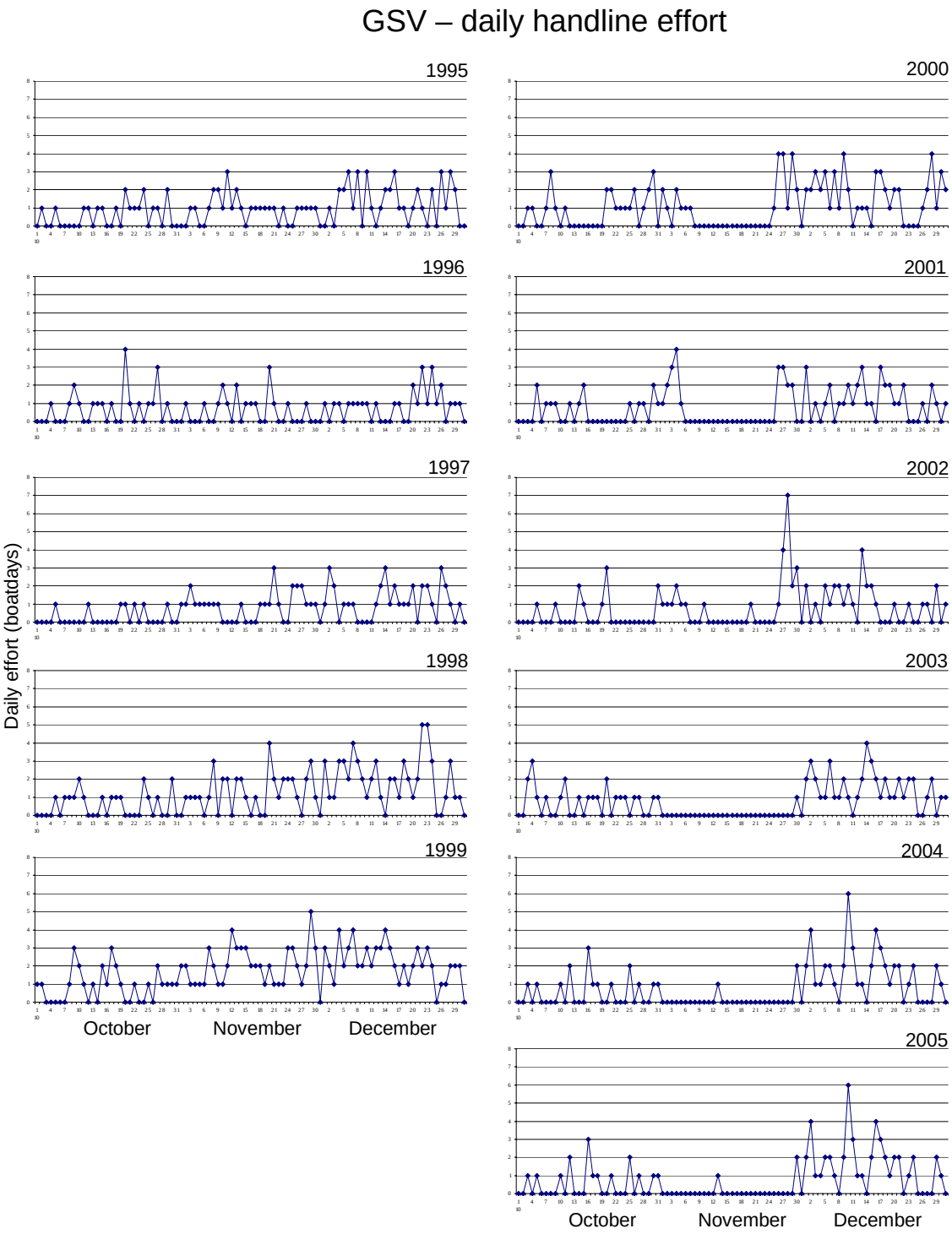

Fig. 4.14. Daily reported fishing effort on snapper in GSV for the three month period of October to December for every year from 1995 to 2005.

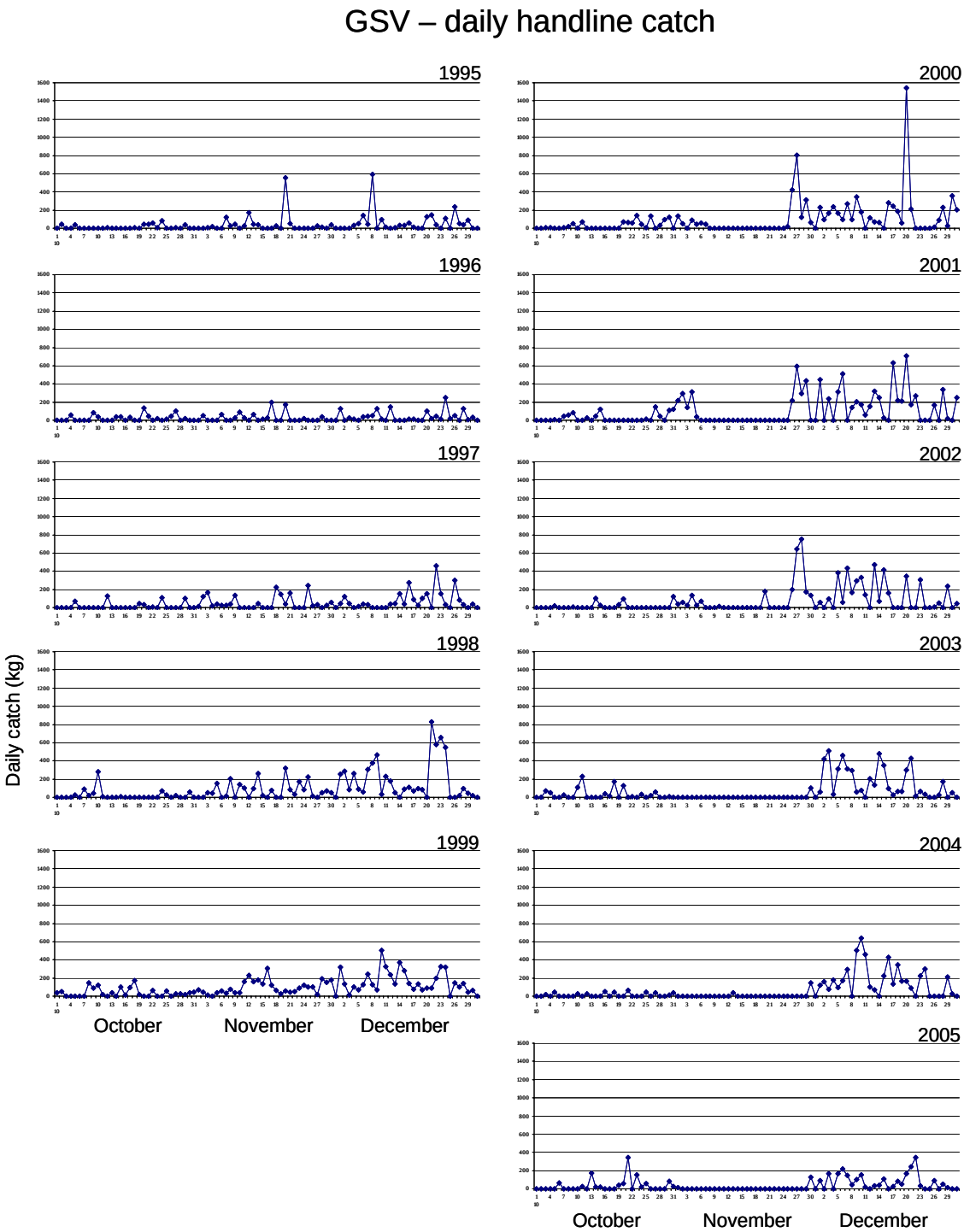

Fig. 4.15. Daily reported fishing catch of snapper in GSV for the three month period of October to December for every year from 1995 to 2005.

4.5 SAFCOL fish market - Daily sale weights and prices

4.5.1 2004-05

During the two-month period immediately before the closure in 2004 the amount of snapper that was auctioned per day was generally between several hundred to one thousand kg, but rarely greater (Fig. 4.16a). Immediately on the reopening of the fishery the daily total increased to greater than 4,000 $kg.d^{-1}$. An amount of 2,500 $kg.d^{-1}$ was sustained for a further two days before the amounts dropped to less than 2,000 $kg.d^{-1}$. Apart from two days when the amounts exceeded 3,000 $kg.d^{-1}$, the weight of snapper auctioned on a daily basis through the remainder of December was generally less than 2,000 $kg.d^{-1}$, which then fell to less than 1,500 $kg.d^{-1}$, for the majority of January.

Although the average price paid in September and October varied between $8 - $11 per kg, there were two periods of variation in price (Fig. 4.16b). The first period was from early September until mid-October during which there was a general increase in price. From then until the end of October there was general decline in the average price. Nevertheless, on the 1st December 2004 on the reopening of the fishery the average price paid was as low as $4.85 per kg. This increased quickly over the next few days to greater than $6 per kg, before increasing steeply to around $11-12 per kg just prior to Christmas. In January the prices declined from greater than $9 per kg at the start of the month to $6-7 per kg by the end of the month.

4.5.2 2005-06

There were similar variations in the daily volume of snapper auctioned and the average price in 2005-06 as there had been in the previous year (Fig. 4.16c). The average daily auction weight was 410.5 kg through September and October, although this was highly variable. This increased to 3,860 kg immediately on the opening of the fishery. Such high daily auction amounts of up to 4,000 kg, and even greater were then sustained until just prior to Christmas. The amounts then dropped off considerably from about the first week of January 2005 and onwards.

The price per kg increased considerably from less than $8 per kg to around $12 per kg by mid October before falling again to $10 per kg by the end of October (Fig. 4.16d). The price during the first few days after the reopening of the fishery was between $5-7 per kg. From then on the price was highly variable on a daily basis, ranging between $5 and $12 per kg, but nevertheless conforming to a generally increasing trend through December and January.

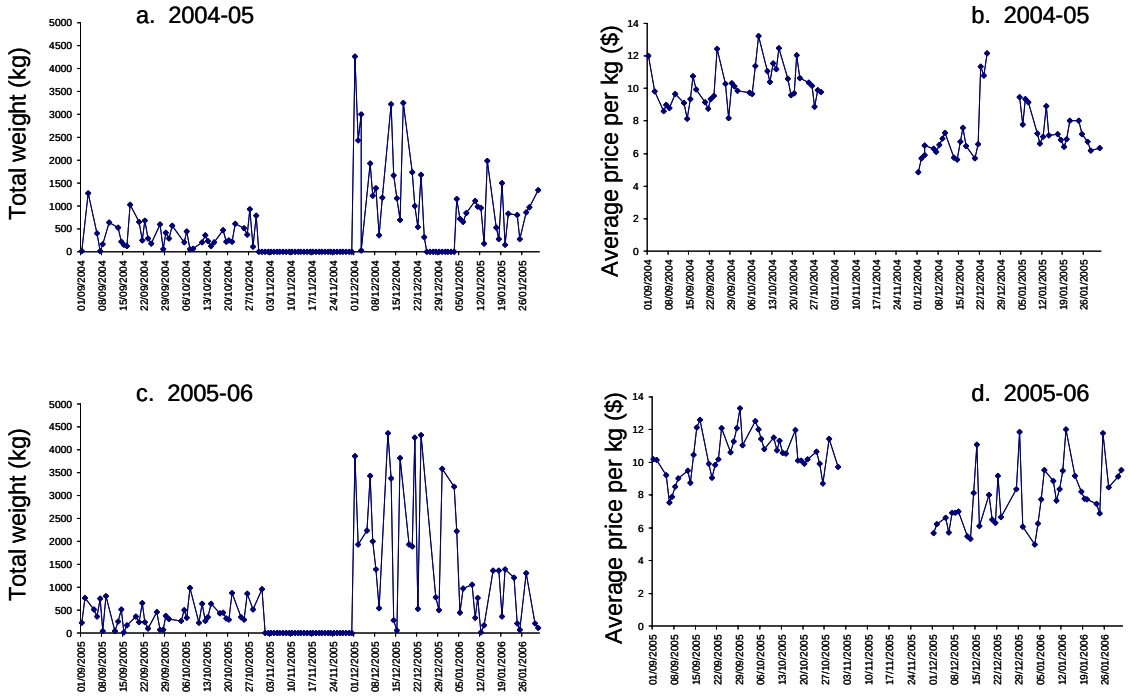

Fig. 4.16 a. Total weight of snapper sold on a daily basis through the SAFCOL market during the five-month period of September 2004 to January 2005. b. Average price per kg, on a daily basis, for which snapper were sold in 2004-05. c. Total weight of snapper sold on a daily basis through the five-month period of September 2005 to January 2006. d. Average price per kg, on a daily basis, for which snapper were sold in 2005-06.

5. DISCUSSION

5.1 Context and approach of this study

In the late 1990s a drop in the commercial longline catch and CPUE for snapper in the South Australian Marine Scalefish fishery suggested a reduction in biomass of the large, old fish, which indicated a need to review the management arrangements for this species. This review resulted in the suggestion of two management options; introduction of a fishery closure as a means of reducing fishing effort, or introducing a maximum size limit to provide some protection for the large, old fish (Shanks 2000). The potential effectiveness of both these strategies were considered independently using yield-per-recruit and egg-per-recruit modelling (McGarvey 2004). The modelling identified that a reduction of fishing effort by 10% would improve the sustainability and efficiency of the fishery. This would increase egg production, but simultaneously provide a marginal increase in fishery production, and thereby maintain the economic viability of the fishery. Such positive effects for the fishery from a closure would relate to individual fish being left in the water longer prior to capture, thus providing them with opportunity to grow more and to produce more eggs.

As a result of the change to the management arrangements a regime of fishery closure(s) has been implemented in the South Australian snapper fishery in every year since 2000. Since the intention of the closures was to reduce fishing effort, their effectiveness must relate to this having been achieved. Yet, it is difficult to assess whether fishing effort was actually reduced because the snapper fishery is part of the multi-species Marine Scalefish Fishery where fishers can swap between numerous, different, target species, according to the availability and marketability of those species that vary through time. In fact, it is evident that for snapper over the relatively short time period of 12 years from 1994 to 2005 that the biomass changed considerably, increasing from its possible lowest to possible highest levels. As such, there was a general increase in targeted effort that resulted in an associated increase in targeted catch. Clearly, the effectiveness of the closures had to be assessed in the context of these changes to biomass and levels of targeted catch, effort and CPUE. The approach used here was to determine whether the closures reduced effort below a level that it would have been had there been no closures.

5.2 Consideration of commercial catch and effort data

From consideration of the monthly, targeted-effort data that were summarised across triennia, it is clear that the patterns of fishing effort were different between the pre-closure and the closure years. This was most dramatically demonstrated by the monthly ratios of Nov_{ef}/Oct_{ef} and Nov_{ef}/Dec_{ef}. These ratios differed significantly over time and were particularly low during the years of 2003-05. Such data indicate that the fishery closures did significantly modify the patterns of fishing effort through these several months. However, such a redistribution of fishing effort does not necessarily mean that annual fishing effort was reduced relative to what it would have been had there been no closures, because fishers may have compensated for the lack of effort during the closure periods by expending considerably more effort both before and after the closures.

Consideration of the patterns of daily fishing effort provides a means of assessing whether fishers did modify their fishing practises, with respect to effort, before and after the closures. The patterns of daily fishing effort provided no evidence of a significant increase in effort through October prior to the start of the November closures in the years of 2000-05. However, there were some clear differences in the fishing effort through late November and early December, between the pre-closure and closure years. For each of the three regions there was a substantial increase in fishing effort immediately on the reopening of the fishery in each year from 2000 to 2005. However, these periods of increased effort usually lasted for only several days before dropping to lower levels that were sustained until the pre-Christmas fishing period. Thus, it is unlikely that the short duration of this immediate increase in effort would have been sufficient to negate the effects of the lower effort associated with the fishery closures. This was particularly the case for the years of 2003-05 when each November closure included almost the entire month.

As indicated above, the intention of implementing the closures was to reduce fishing effort. Nevertheless, it is apparent from the time-series on fishery catches that the closures were also effective in modifying the patterns of distribution of fishing catches. Catch strongly reflected the patterns of fishing effort. Clearly when effort was low then catch was also low, whilst the peaks in handline catch in each region through the October to January periods reflected increases in fishing effort, presumably as the fishers targeted the spawning aggregations. For the same reason as outlined above with respect to fishing effort, it is also likely that the catch of snapper in each closure year was reduced relative to what it would have been had the closure not been implemented. The daily catch data indicated that in each region the pre-

closure catches were relatively small. For some years in both NSG and GSV there was a substantial increase in catch immediately after the closure, which lasted only a few days before dropping to a level that was sustained until before Christmas. Such an increase was not a feature of the data for SSG, where a more consistent daily catch record was retained until the Christmas period.

The high December catch rates were evident as high volumes of snapper that passed through the SAFCOL fish market. The immediate post-closure increase in volume was more evident for 2004-05 than for the following year. Nevertheless, these high volumes were not necessarily a consequence of the closure, but rather reflected the high December catch rates, that have been a consistent feature of this fishery. As such, the much-reduced price paid to fishers in December in both 2004-05 and 2005-06, relative to the prices paid in October, presumably relate more to the volume of fish available in the market than as a consequence of the closure.

5.3 Estimated reductions in fishing effort

It was concluded above that fishing effort was effectively reduced as a consequence of the fishery closures, and the month-long closures in November of 2003-05 appear to have been particularly effective in reducing effort. Whilst it is beneficial to quantify the reduction in annual fishing effort attributable to the closures the process for achieving this is complicated by the other numerous factors that also influence effort within and between years in this fishery. Here the linear trend for the estimates of effort from September, October and December for each triennium was used to provide an estimate of the effort for November for that triennium, using regression analysis (Fig. 5.1). Using this method the monthly trends in fishing effort that were summarised in Figs. 4.2b-4.7b were used to estimate the reduction in annual fishing effort attributable to the closures separately for handlines and longlines for each of the three regions of NSG, SSG and GSV. The estimated monthly effort for November was then added to the reported total effort for the year, thus providing a theoretical estimate of annual fishing effort had a closure not been implemented. The percentage difference between the reported and estimated total annual fishing effort was then calculated.

The estimates of the percentage reduction in annual fishing effort were quite variable according to region and gear type (Table 5.1). The period of 2003-05 produced the highest estimated reductions in effort because of the longer closure, but the estimates for 2000-02 are under-estimates, as they do not include the effects of the August closures. The estimates for 2003-05 ranged from 4.6 to 11.8%. Furthermore, greater reductions in effort were evident for

the handline fishery, which is beneficial as this sector accounts for the greater proportion of fishing effort.

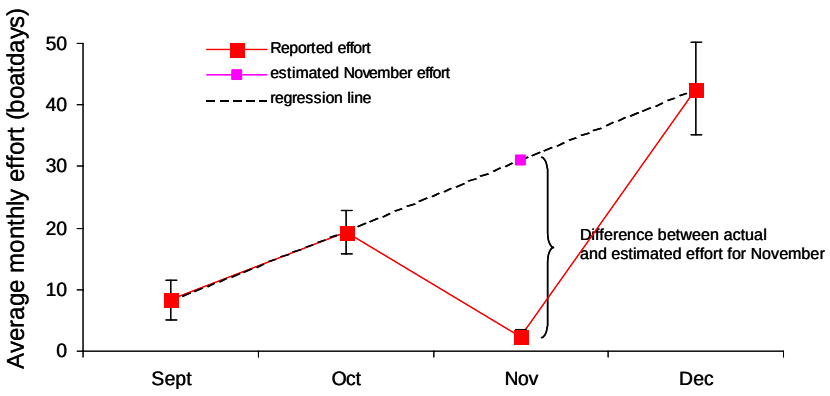

Fig. 5.1. Example of methodology used to calculate the theoretical estimate of fishing effort for November, in the absence of a closure, based on linear regression analysis of the effort data from September, October and December. The data are handline data for GSV in 2003-05. The difference between the estimated effort and the actual reported effort is indicated.

Table 5.1 Summary of results based on regression analyses showing the reported and estimated values of effort in November, and the reported and estimated values of annual fishing effort, and the percentage difference between the annual values, i.e. the reduction in effort attributable to the fishery closure.

Region	Triennium	Gear	Reported effort in Nov. (boatdays)	Estimated effort for Nov (boatdays)	Difference (estimated – reported)	Reported annual effort (boatdays)	Estimated annual effort (boatdays)	% reduction in annual effort
NSG	00-02	HL	118	210.7	92.7	1630.3	1723	5.4
SSG	00-02	HL	75.3	112.2	36.8	766.3	803.1	4.6
GSV	00-02	HL	25.7	34.2	8.5	324	332.5	2.6
NSG	03-05	HL	15.7	117.6	101.9	1104	1205.9	8.5
SSG	03-05	HL	10.3	98.2	87.9	657	744.9	11.8
GSV	03-05	HL	2.3	31.1	28.8	569.3	598.1	4.8
NSG	00-02	LL	11.7	30.1	18.4	421	439.4	4.2
SSG	00-02	LL	3.7	10.9	7.2	148	155.2	4.7
GSV	00-02	LL	7.7	9.4	1.8	181	182.8	1.0
NSG	03-05	LL	2.3	10.7	8.4	173	181.4	4.6
SSG	03-05	LL	1	15.5	14.5	224.3	238.8	6.1
GSV	03-05	LL	1	13.8	12.8	235.3	248	5.1

5.4 Conclusions

The monthly trends in fishing effort showed clear differences between the pre-closure and the closure periods. The effects of the fishery closures are apparent in the data for each of NSG, SSG and GSV as perceptible reductions in effort for both August and November in 2000-02, and even greater decreases in fishing effort in November of 2003-05. These reductions are apparent despite the changes in biomass, fishing effort, catch and population structure that the snapper population experienced through the period of 1994 to 2005. Nevertheless, such reductions in fishing effort in November do not necessarily mean that annual effort was reduced, since fishing effort may have been redistributed to before and after the closures.

The analysis of data on daily fishing effort provided a means of assessing whether effort was higher before and after the closures. These data for each of NSG, SSG and GSV indicated that effort did not increase prior to the November closures. There was, however, increased effort on the reopening of the fishery on the 30th November and early December. However, this inflated effort was only sustained for several days, before dropping to a level that was sustained for longer. As such, it is unlikely that the inflated effort would have negated the effects of the closure.

Consideration of the two main datasets, i.e. the monthly trends in fishing effort between different triennia and the daily patterns of fishing effort, strongly suggest that the snapper fishery closures were effective in reducing targeted effort on snapper. The levels of reduction in annual fishing effort attributable to the closures were estimated using a simple method based on linear regression analysis. The estimates varied between regions, triennia and gear types. The reductions for handline effort ranged between 2.8 and 11.8% per annum, and for longlines from 1.0 to 6.1% per annum.

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