

Assessing the effects of South Australia's snapper spawning spatial closures



AJ Fowler and R McGarvey

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Report to PIRSA Fisheries and Aquaculture

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EXECUTIVE SUMMARY

In 2013/14, snapper spawning spatial closures were implemented in South Australia to protect spawning aggregations of snapper. There were four circular closures of 4 km radius in Northern Spencer Gulf and one closure in Northern Gulf St. Vincent. The duration of the closures was from 15 December 2013 to 31 January 2014 (reference period). This report assessed the impacts of these spatial closures on the catch and effort by the commercial and charter boat sectors of the Marine Scalefish Fishery.

The assessments for the two sectors were based on extracts of fishery data provided by SARDI's Information Systems and Support Program. For both sectors and the regions of Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG) and Northern Gulf St. Vincent (NGSV), estimates were calculated of displaced catch and effort attributable to the spawning spatial closures. These were based on the proportions of annual catch taken or effort expended in the reference period in 2013/14, compared with during the same period in years prior to implementation of the closures. For the commercial sector, variation amongst years in the proportion of catch and effort taken or expended during the reference period necessitated the use of two methods to calculate displaced catch and effort.

For NSG, time series of catch, effort and catch per unit effort indicated that in 2013/14, fishable biomass was at a historically low level. The estimates of displaced catch and effort attributable to the spatial closures were considerable, at 7.6 to 32.1 t and 46 to 202 mandays, respectively. For SSG, fishable biomass was also relatively low in 2013/14. The estimates of displaced catch and effort were <1.0 to 8.8 t and 0 to 81 mandays, respectively. For NGSV, fishery statistics indicated that fishable biomass in 2013/14 remained at a record high level. The estimates of displaced catch and effort for this region were relatively minor at 0 to 5.5 t and 0 to 130 mandays, respectively.

Daily data from the charter boat sector were considered from 2007/08 to 2013/14. In NSG and SSG, charter boat catches declined in both 2012/13 and 2013/14. Nevertheless, the annual proportion of catch and effort in the reference period showed little variation over time, including in 2013/14. This suggests that the spatial closures had minimal impact on the charter boat sector. In NGSV, charter boat catch and effort increased in 2012/13 and 2013/14, however no impact was attributable to the spawning spatial closures.

An intensive, systematic plankton survey was done in NSG during 11 – 15 December 2013, immediately before the first implementation of the snapper spawning spatial closures. This provided an opportunity to assess whether the four sites chosen for closure in this region were significant egg production sites for snapper. Although, it is not yet possible to confirm the identification of snapper eggs, there were a number of areas of high abundance of 'possible' snapper eggs that largely conformed to the locations of the snapper spatial closures. This provides some preliminary evidence that the snapper spawning spatial closures in NSG have been located in the right places.

Overall, the most significant impacts of the spatial spawning closures were in NSG where there was limited opportunity for fishers to operate outside the closure sites because of the low regional biomass and tendency for snapper to form spawning aggregations in this region. Alternatively, in NGSV there was greater opportunity for fishers to operate successfully outside the single spatial closure as the regional biomass was higher and snapper do not aggregate to the same extent as in NSG. As yet, it is difficult to assess whether the snapper spatial spawning closures in 2013/14 enhanced recruitment. This relates to snapper being a long-lived species for which recruitment is highly variable. As such, it may take a number of years for the stocks to respond to the closures. A second plankton survey scheduled for December 2015 and stock assessment scheduled for 2016 will provide further opportunities to assess the spawning closures and stock recovery.

INTRODUCTION

From 2007 to 2011, the annual commercial catches of snapper (*Chrysophrys auratus*) by South Australia's (SA) Marine Scalefish Fishery were at record high levels, with the catches strongly associated with a significant shift in the spatial structure of the fishery (Fowler et al. 2013). Commercial catch, effort and catch per unit effort (CPUE) increased considerably in two regions, i.e. Northern Gulf St. Vincent (NGSV) and the South East (SE), where snapper fishing effort had previously been very low. At the same time, however, the contributions of the traditional snapper fisheries in Northern Spencer Gulf (NSG) and Southern Spencer Gulf (SSG) were declining. In 2012 and 2013, these declines resulted in both regional fisheries being assigned the status of 'transitional depleting' (Jackson et al. 2012, Fowler et al. 2013).

The unprecedented levels of targeted fishing effort that produced record catches of snapper in NSGV and the SE and unprecedented, large declines in both NSG and SSG led to concern in the industry and community about the long-term sustainability and economic viability of SA's snapper fishery. Consequently, in May 2011, PIRSA Fisheries and Aquaculture established the Snapper Working Group (SWG), to review and make recommendations about the management arrangements for the fishery. Through this process, findings of a recent study of snapper behaviour suggested that the spawning aggregations might be particularly susceptible to disturbance by the fishing activity that takes place after the annual seasonal closure in November each year (Fig. 1) (Fowler unpublished data). As such, the focus of the SWG became to establish management arrangements that would maintain a sustainable snapper fishery by not only limiting the impact of the commercial sector on snapper stocks but also by optimising opportunities for spawning and recruitment.

Following the processes of the SWG, on 1 January 2012 an interim daily catch limit of 800 kg.day⁻¹ was introduced for commercial fishing in SG and GSV. Then, in October 2012, additional management changes were made, which included:

1. a 15-day extension to the annual State-wide snapper fishing closure that was implemented for the commercial sector in December 2012 and then also applied to the general recreational and charter boat sectors in December 2013 (Fig. 1);
2. a daily commercial catch limit of 500 kg that was introduced for all South Australian coastal waters from 15 December 2012, to help control the level of commercial effort on snapper stocks;

3. a restriction for commercial fishers to using a maximum of 200 hooks on set lines (reduced from 400 hooks) when operating in SG and GSV, to assist in constraining catch and minimising the discard of excess snapper that could result from the newly imposed daily catch limit.

Subsequently, a further important change was made to the management arrangements for snapper. In June 2013, following a significant process of consultation, PIRSA Fisheries and Aquaculture announced the establishment of five species-specific, spatial-temporal closures located in the northern parts of both gulfs that were designed to extend protection of important spawning aggregations for the entire reproductive season. These closures would begin on 15 December, when the seasonal closure for the whole State was ending, and continue to 31 January. These snapper spawning spatial closures were first implemented in the summer of 2013/14. There are four such closures located in NSG: the Illusion; the Santa Anna; the Estelle Star; and Jurassic Park (Fig. 2). The one spatial closure in NGSV is located off-shore from the township of Ardrossan. All closures are circular in shape and extend to a 4 km radius from a fixed point. The closure at Estelle Star extends marginally into MFA29 and therefore into SSG.

The snapper spawning spatial closures have been in place for only the last spawning season, i.e. from 15 December 2013 to 31 January 2014. This was the same year that the State-wide, seasonal closure was extended to 15 December for the charter boat sector (Fig. 1), but the year following the extension of the seasonal closure for the commercial sector. Immediately prior to the implementation of the snapper spatial spawning closures, SARDI undertook a plankton survey in NSG. This was a part of an FRDC-funded project aimed at estimating the spawning biomass of snapper, based on egg production and adult reproductive information. The systematic sampling for snapper eggs throughout NSG provided an opportunity to confirm whether the four sites chosen for closure in this region are significant egg production sites for snapper.

PIRSA Fisheries and Aquaculture is now undertaking a review to assess the impacts of the new spatial spawning closures. This report informs the review process by evaluating the effects that the closures had on the commercial and charter boat fishing sectors. To achieve this assessment, the following objectives were addressed:

1. to provide regional, annual time-series of commercial fishery statistics for snapper as presented in stock assessment reports (e.g. Chpt 3 in Fowler et al. 2013);
2. to provide regional estimates of displaced catch and effort for the commercial and charter boat sectors attributable to the snapper spawning spatial closures in 2013/14;

- to provide the results of the egg survey undertaken in NSG in December 2013 as part of the assessment of the daily egg production method (DEPM) for snapper. The focus here was on 'possible' snapper eggs, as the genetic work to confirm taxonomic identification of the eggs has not been completed.

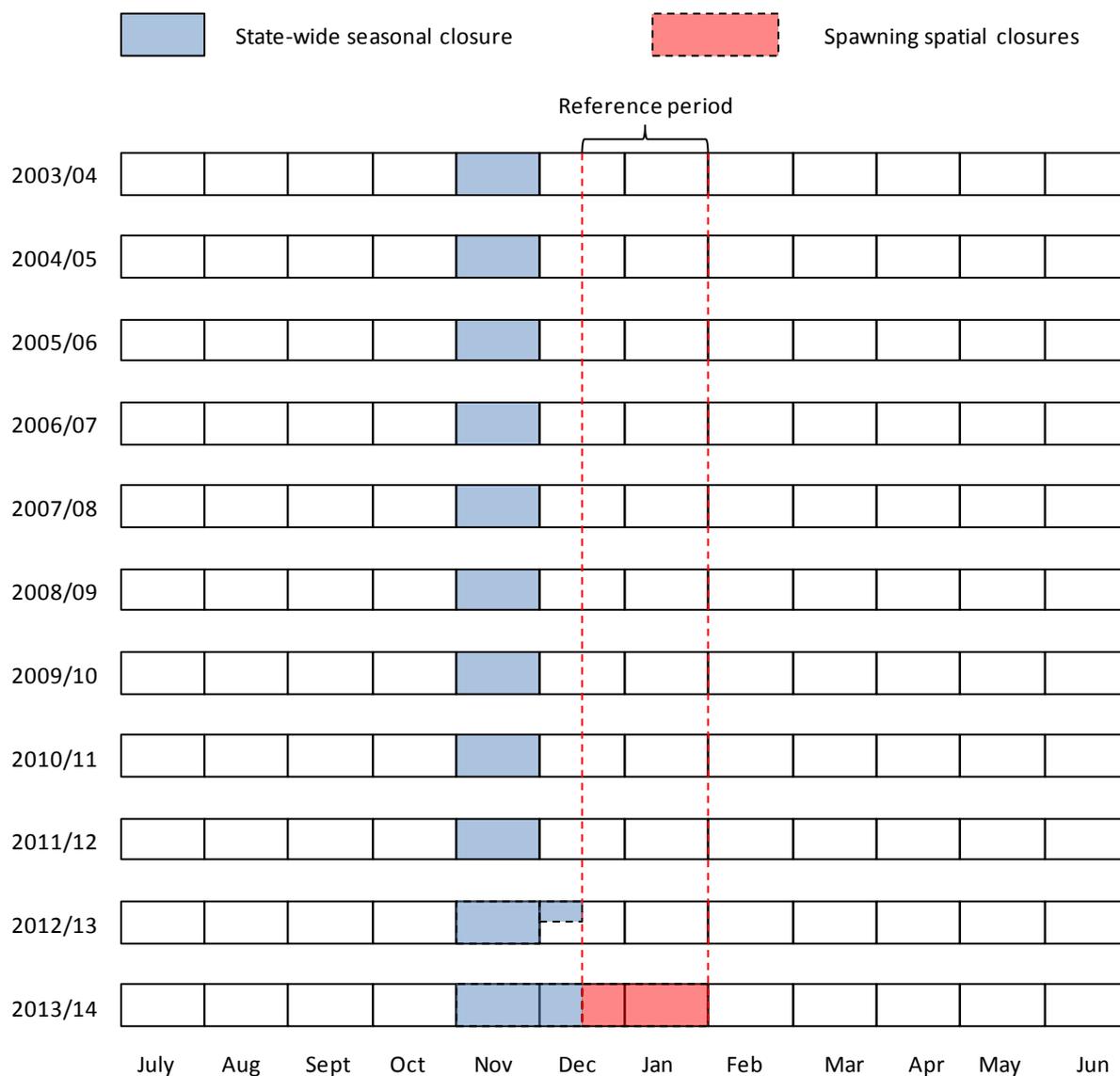


Fig. 1. Diagrammatic representation of the months and financial years from 2003/04 to 2013/14, indicating when the seasonal closure applied in each year. The seasonal closure was extended for the commercial sector in 2012/13, but for the recreational sector, including the charter boat sector, in 2013/14. The snapper spawning spatial closures were first implemented in 2013/14.

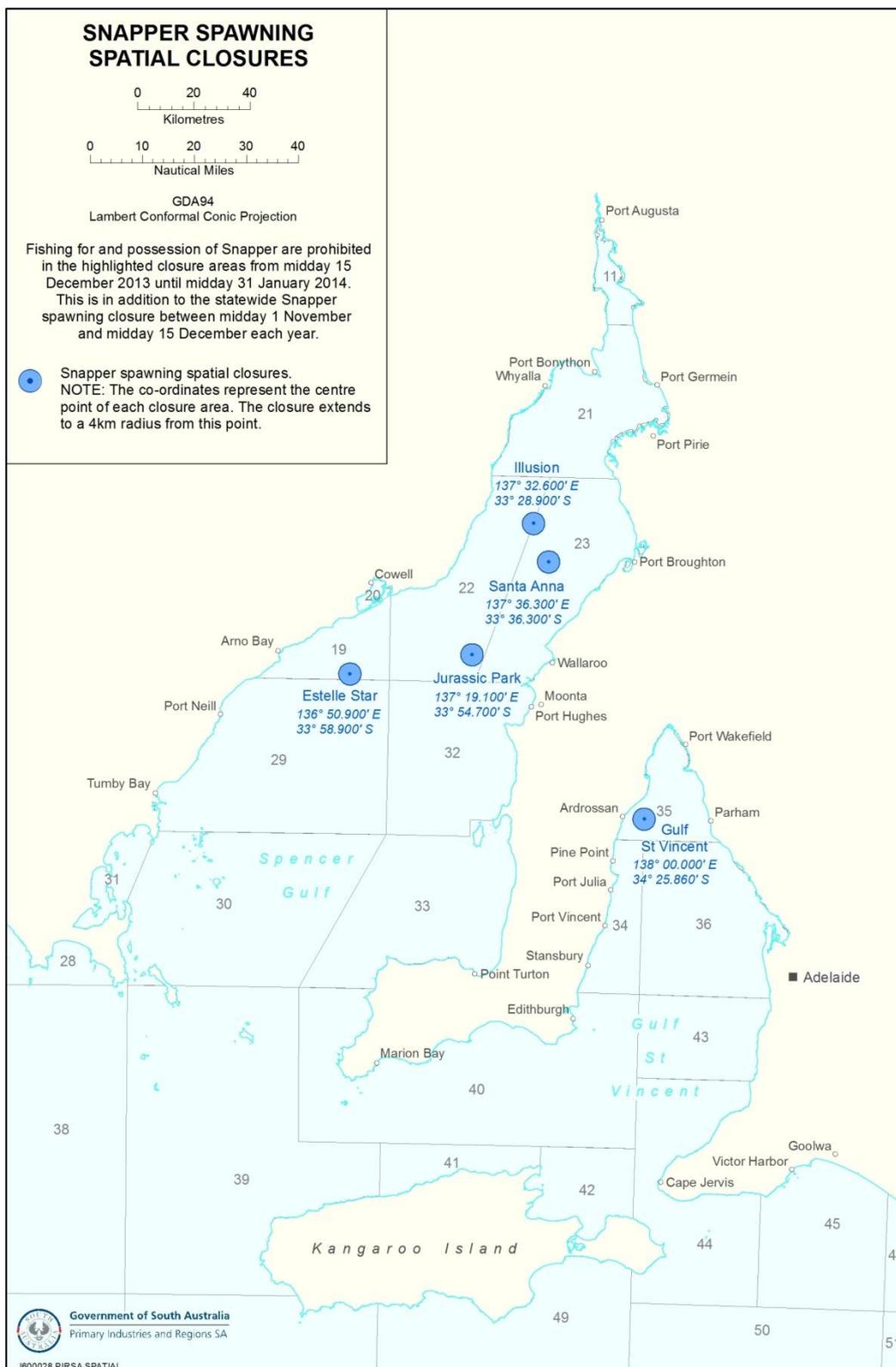


Fig. 2. Map of Spencer Gulf and Gulf St. Vincent showing the locations of the five snapper spawning spatial closures.

MATERIALS AND METHODS

Commercial sector

Since 1983/84, commercial fishers in SA's Marine Scalefish Fishery have been required to submit a monthly catch return that details their catches for the preceding month. Prior to 2003/04, such data were reported by fishers at the monthly time scale. In 2003/04, it became mandatory to report commercial catch and effort data at the daily temporal scale, thereby allowing for more refined temporal analysis of the fishery statistics. For this assessment, the commercial fishery data for snapper were provided by SARDI's Information Systems and Database Support Program at two temporal scales: monthly data for all years from 1983/84 to 2013/14; daily data from 2003/04 to 2013/14. The two datasets were analysed independently after each was organised to allow data extractions and summaries by financial year and region, with the regions of interest of NSG, SSG and NGSV (Fig. 3).

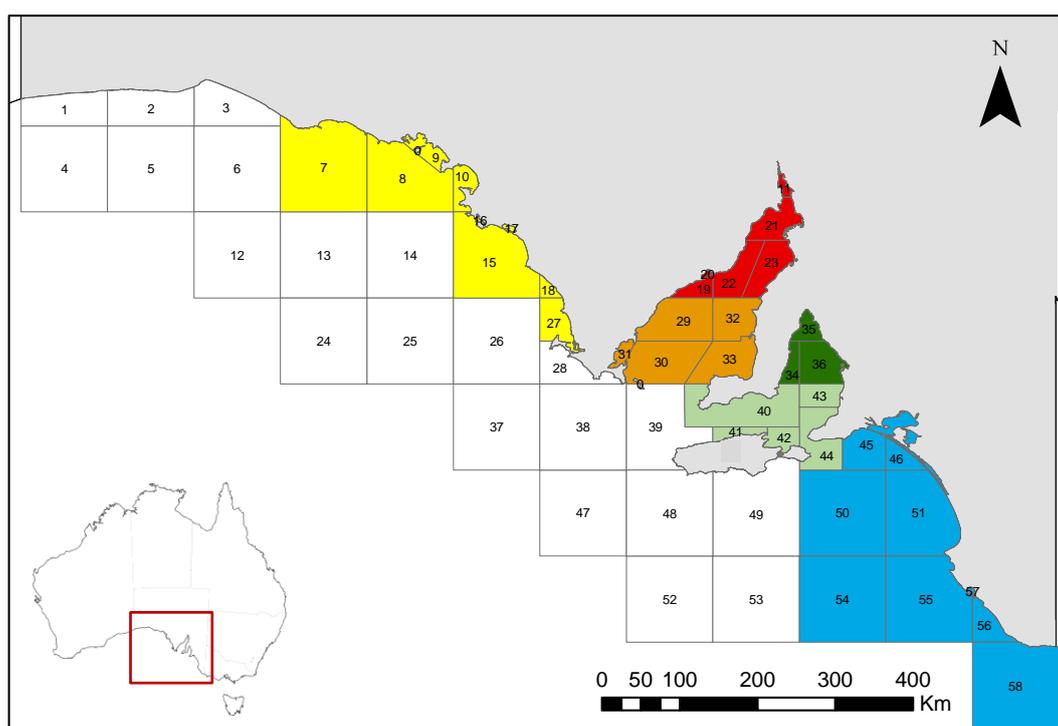


Fig. 3. Map of South Australia showing the Marine Fishing Areas (1° blocks) that are used for collection of fishery statistics in the Marine Scalefish Fishery. The three regions considered in this analysis of commercial fishery statistics were: Northern Spencer Gulf (red), Southern Spencer Gulf (orange), Northern Gulf St. Vincent (dark green).

The monthly data were used to generate annual time-series of, regional catch and effort totals for the handline and longline gear types. Targeted catch and effort data were used for

both gear types to be consistent with the regional presentation of data in the stock assessment reports (Fowler et al. 2013).

The commercial fishery data reported at the daily level from 2003/04 to 2013/14 were used to generate estimates of displaced catch and effort attributable to the new snapper spatial spawning closures. These reported totals for total catch and targeted effort were combined across all gear types at the regional spatial scale. Each financial year was divided into two time periods: (1) 15 December to 31 January; (2) the remaining period of each financial year, i.e. 1 July to 14 December and 1 February to 30 June. These two periods will henceforth be referred to as the 'reference' and the 'remaining' periods, respectively. Then, for each financial year, the proportions of catch and effort taken during the 'reference' and 'remaining' periods were calculated.

The displaced catch and effort in 2013/14 attributable to the spatial spawning closures, by region, were estimated using the observed proportion of catch and effort in the 'reference' period relative to the 'remaining' period from the previous years of 2003/04 to 2012/13. This proportion in the last 10 years prior to extending the spawning closure quantifies how much catch and effort was normally taken in the time of the spatial-temporal closure in each region. The process of achieving this is described here for total catch, but was also applied for targeted effort. First the expected catch for the 'reference' period in 2013/14 was calculated as:

$$1. \quad C_e = C_{\text{rem}} \times \frac{P_{\text{ref}}}{(1 - P_{\text{ref}})}$$

where C_e = expected catch for 'reference' period in 2013/14, C_{rem} = catch in 'remaining' period in 2013/14, P_{ref} = proportion of annual catch taken in 'reference' period averaged across years 2003/04 to 2012/13.

Then the estimate of absolute displaced catch was calculated as the difference between the estimated catch C_e , and the observed catch during the 'reference' period

$$2. \quad C_d = C_e - C_{\text{ref}}$$

where C_d = displaced catch from reference period in 2013/14, C_{ref} = actual catch recorded in reference period in 2013/14.

Finally, the percentage displaced catch was calculated from the displaced catch, relative to what the catch would have been had there been no spawning spatial closure in place

$$3. \quad \%D = \frac{C_d}{(C_d + C_{tot})} * 100\%$$

where %D = % displaced catch, C_{tot} = total recorded annual catch in 2013/14.

Note that in applying this method it became apparent for both NSG and SSG that there was significant variation in the estimates of the proportion of annual catch taken during the 'reference' period across the years of 2003/04 to 2012/13 due to a significant increase in the latter year. This complicated the process of estimating displaced catch in 2013/14, because of the poor estimate of average proportion (P_{ref}) that could be calculated. Consequently, it was decided to provide two estimates of displaced commercial catch based on using two estimates of P_{ref} in equation 1. The two estimates of P_{ref} used were: Method (1) the proportion of annual catch taken through the reference period averaged across the years of 2003/04 to 2011/12; Method (2) the single estimate of the proportion of annual catch taken in the reference period in 2012/13. The two methods were also used to estimate displaced targeted effort. For consistency, both Method (1) and Method (2) were used for each region of NSG, SSG and NGSV.

From the application of Methods (1) and (2), some of the resulting estimates of displaced catch or effort were negative. This meant that the actual observed catch or effort during the reference period in 2013/14, i.e. when the spatial closures were in place, exceeded the estimated displaced values. This reflects the inter-annual variability in the system, and meant that there was no perceptible decline in catch or effort in the reference period relative to previous years, and so no evidence of reduced catch that could be attributed to the spatial closures. In these situations the estimates of displaced catch and percentage displaced catch (or effort) were set to zero.

Charter boat sector

Whilst catch returns have been provided by South Australia's charter boat operators since September 2005/06, the data are most reliable from July 2007 onwards. As such, all daily records of charter boat fishing operations that produced catches of snapper were provided for the period of July 2007 to June 2014 by SARDI's Information Systems and Database Support Program. The data on total catch of snapper per fishing trip and targeted effort in terms of mandays directed at snapper were considered in this analysis. The number of mandays was equivalent to the number of clients on board, who targeted snapper through that day. As data on fishing effort are recorded in the database separately for different

Marine Fishing Areas, care was taken to ensure that effort was only considered once per day when the totals were being calculated. The data on catch and effort were first organised to generate summaries by financial year and region. Furthermore, the data for each financial year were differentiated into the 'reference' and 'remaining' periods, as defined above for the commercial sector. Then, for each financial year the proportions of the total annual catch and targeted effort taken or expended in the two periods were estimated. The estimates of displaced catch and effort were calculated using the same method described above for the commercial sector.

Snapper egg survey

In December 2013, SARDI undertook a plankton survey throughout NSG, to contribute to estimating spawning biomass of snapper. Systematic sampling was done along a series of east-west oriented transects. These transects were 4 nm apart, whilst stations were separated by 2 nm, with higher sampling intensity around the nominated spawning closure sites. At each station, a vertical plankton tow was done using paired bongo nets. The plankton samples were preserved in alcohol and returned to the lab for sorting. Later, the plankton samples were sorted by removing the fish eggs and larvae, and then dividing the fish eggs into 'possible' and 'unlikely' snapper eggs, based on their morphological characteristics. The distribution and relative abundances of the 'possible' snapper eggs were then graphed in a kernel density map.

RESULTS

Regional analysis of catch and effort statistics (1983/84 to 2013/14)

In Northern Spencer Gulf (NSG), the long-term trends of declining effort since 2002/03 for both the handline and longline gear types continued to 2013/14 (Fig. 4). Targeted effort in 2013/14 was the lowest ever recorded for this region. Targeted handline catch dropped significantly in 2012/13 and continued to fall in 2013/14, to the lowest ever recorded value. Relatively low values for handline and longline CPUE were also recorded in 2013/14. These fishery statistics are consistent with the continuation in decline of the fishable biomass of this region that was identified in 2013 (Fowler et al. 2013).

In 2013/14 for Southern Spencer Gulf (SSG), both targeted handline and longline effort continued their declining trends from the high values recorded in 2006/07 (Fig. 5). Consequently, by 2013/14 targeted handline catch had fallen to the lowest recorded level, which was a fraction of the annual catches taken during the mid 2000s. Furthermore, handline and longline levels were also low in this year. These commercial fishery statistics suggest that the declining biomass in this region previously identified up to 2012 (Fowler et al. 2013), had continued throughout 2013 and 2014.

For NGSV, the estimates of targeted longline catch, effort and CPUE for 2013/14 remained very high (Fig. 6). These data suggest that the high biomass typical of recent years has persisted into 2013/14 (Fowler et al. 2013).

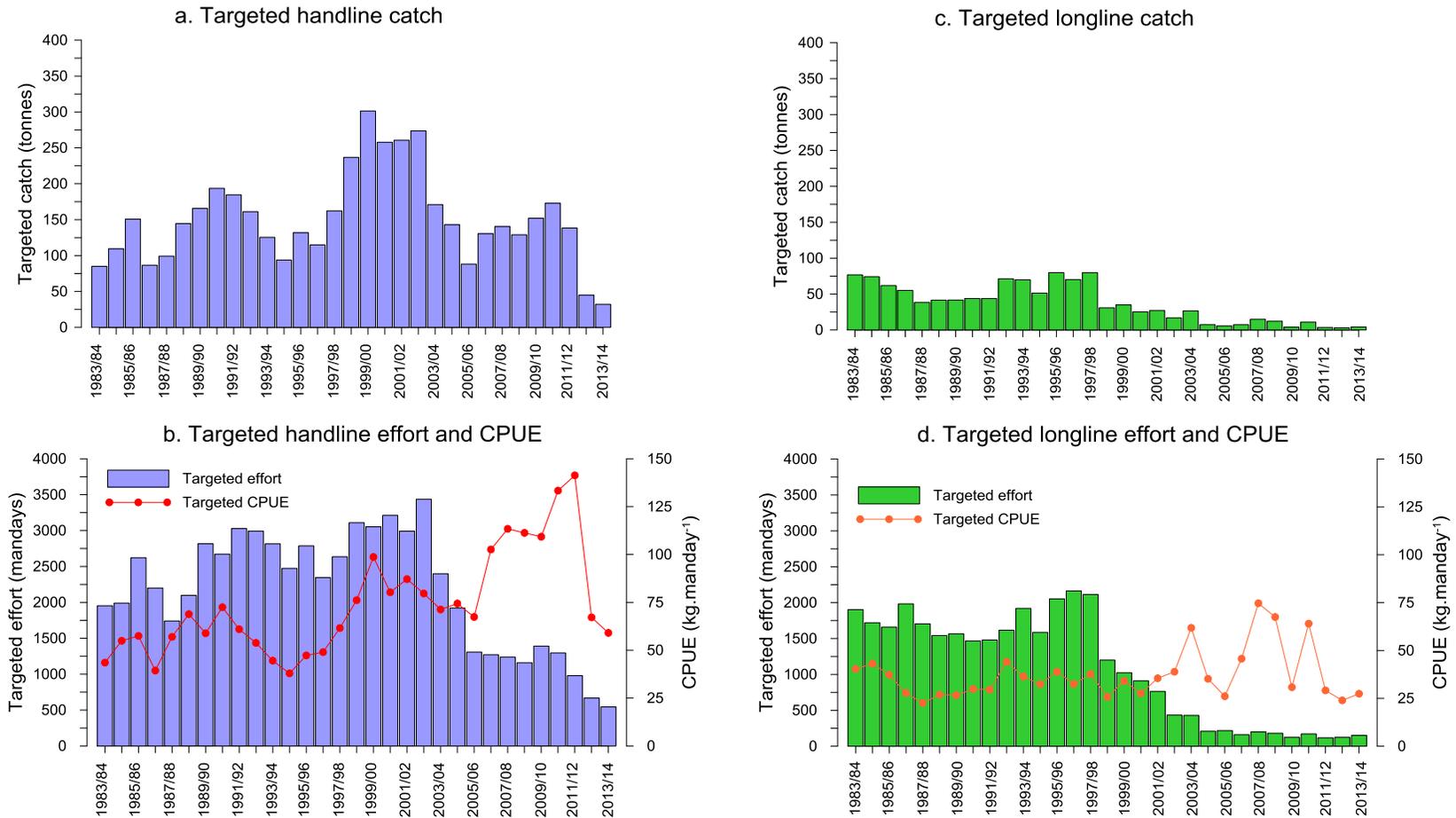


Fig. 4. Northern Spencer Gulf. a. Historical record of targeted catch of snapper by the commercial handline sector; b. Historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

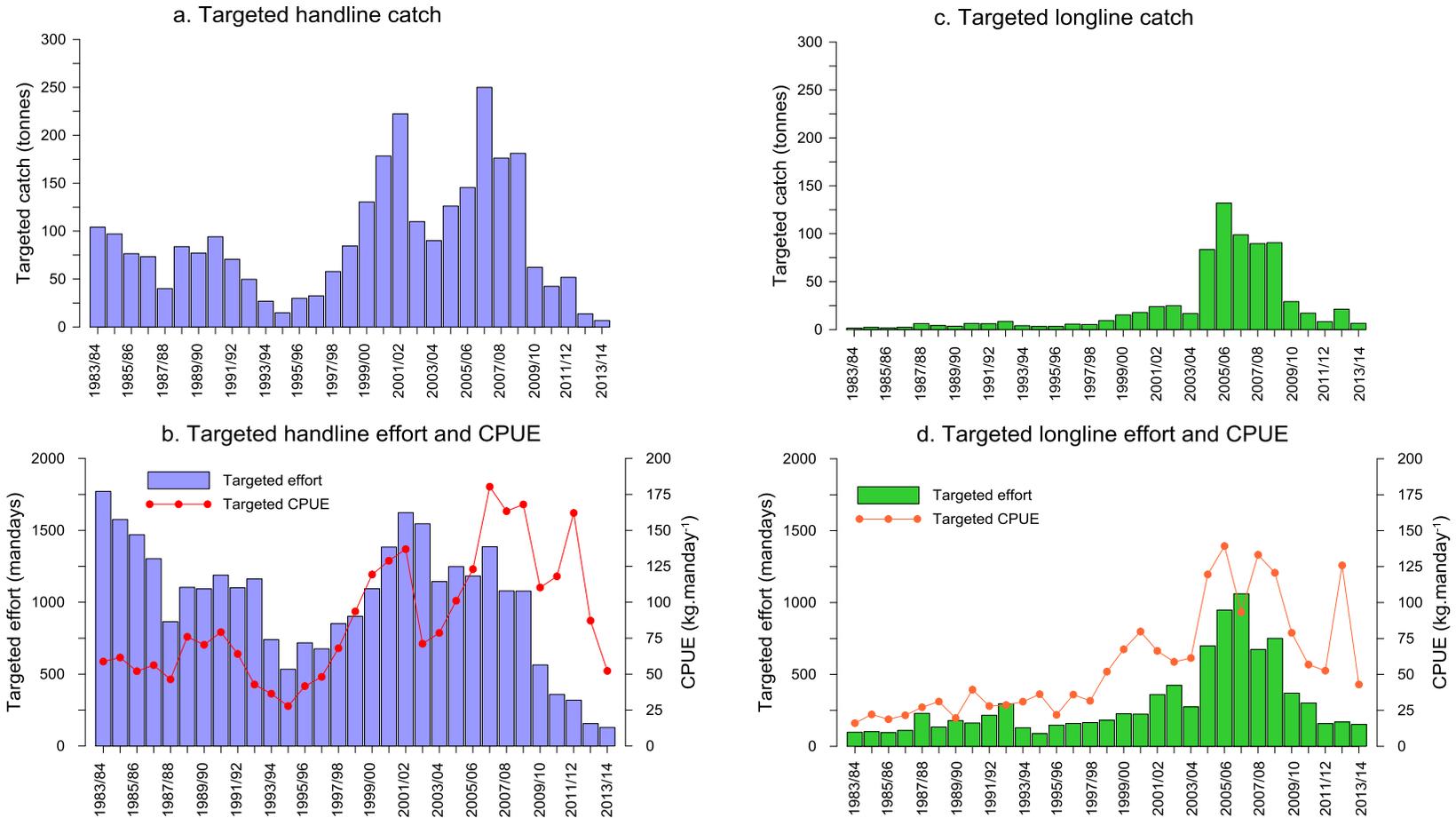


Fig. 5. Southern Spencer Gulf. a. Historical record of targeted catch of snapper by the commercial handline sector; b. Historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

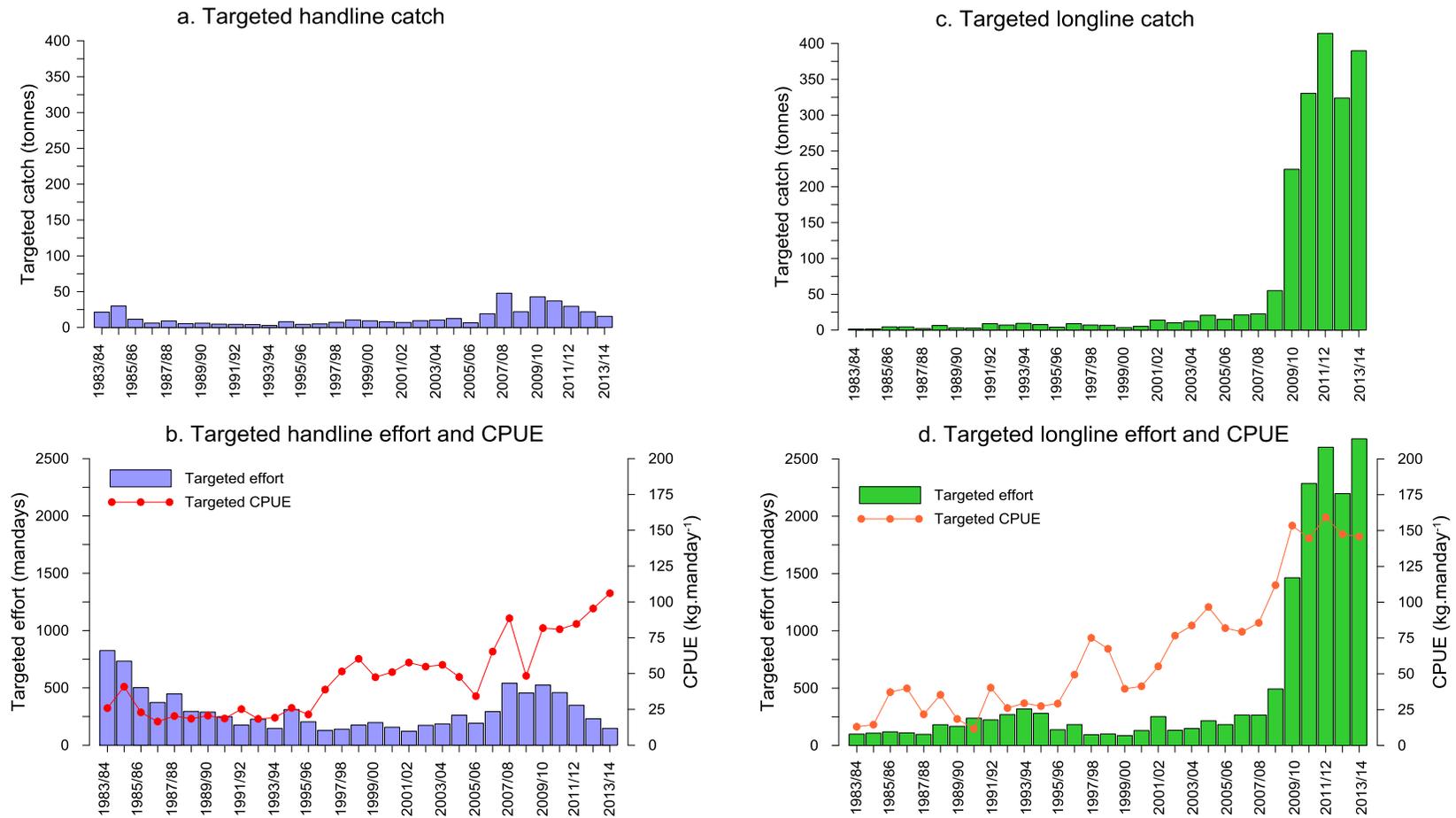


Fig. 6. Northern Gulf St. Vincent. a. Historical record of targeted catch of snapper by the commercial handline sector; b. Historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

Estimation of displaced commercial catch and effort

Northern Spencer Gulf

For NSG, total catch varied considerably between 2003/04 and 2013/14 (Fig. 7). While there was no long-term trend up to 2011/12, total catch declined dramatically in the last two years to 39.6 t in 2013/14. The proportion of the annual catch taken during the 'reference' period was also variable amongst years, ranging from 0.1 to 0.33 in 2011/12. However, it then increased dramatically from 0.11 to 0.5 in 2012/13. This implies a concentration of commercial fishing activity immediately after the reopening of the fishery from the extended closure on the 15 December 2012. The estimated displaced catch in NSG using Method (1) was 7.6 t, a displacement of 16.1% (Table 1). The estimates from Method (2) were 32.1 t, and 44.9%, respectively.

There has also been a significant decline in targeted effort on snapper in NSG from 2003/04 to 2013/14 (Fig. 7). Up to 2011/12, the proportion of annual targeted effort expended during the 'reference' period was relatively consistent at 0.12 to 0.23, but this increased considerably to 0.32 in 2012/13. The estimates of displaced effort from NSG using the two methods were: using Method (1) the displaced effort was estimated at 46 mandays, equivalent to a reduction of 6.2%; from Method (2), the displaced effort was 202 mandays, i.e. a reduction of 22.4% (Table 1).

Table 1. Summary of regional estimates of displaced total catch and targeted effort for South Australia's commercial fishery on snapper, attributable to the introduction of spawning spatial closures in 2013/14. Method 1 – used the proportion from the reference period averaged across the years of 2003/04 to 2011/12. Method 2 – used the estimated proportion for the reference period of 2012/13.

Region	Displaced catch (Method 1) (kg)	Displaced catch (Method 2) (kg)	Displaced targeted effort (Method 1) (mandays)	Displaced targeted effort (Method 2) (mandays)
NSG	7,594 (16.1%)	32,171 (44.9%)	46 (6.2%)	202 (22.4%)
SSG	760 (4.3%)	8,795 (34.0%)	0 (0%)	81 (20.8%)
NGSV	0 (0%)	5,467 (1.3%)	0 (0%)	130 (4.2%)

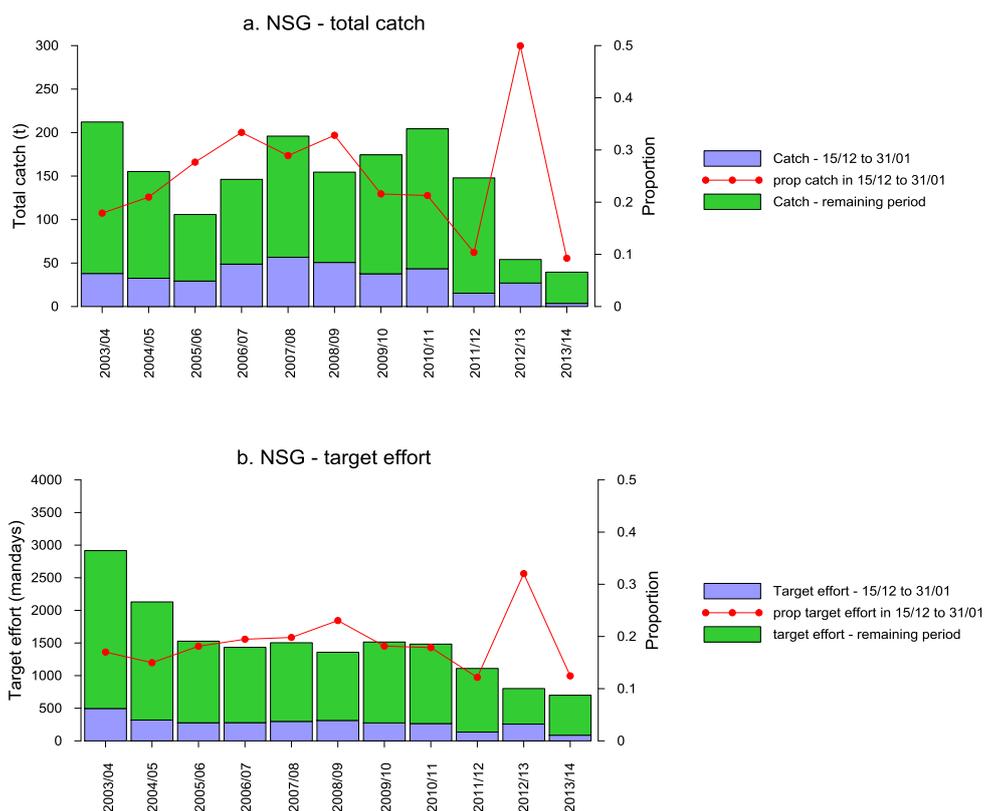


Fig. 7. Northern Spencer Gulf. a. Historical record of total commercial catch of snapper across all gear types, differentiating catch taken in the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual catch taken during the 'reference' period. b. Historical record of the commercial targeted effort across all gear types directed at snapper, differentiating effort expended in the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual targeted effort expended during the 'reference' period each year.

Southern Spencer Gulf

Total annual catch for SSG was relatively high from 2004/05 to 2008/09, but then declined considerably after 2008/09, to the lowest recorded level in 2013/14 (Fig. 8). The proportions of annual catches taken through the reference period for the years from 2003/04 to 2012/13 ranged from 0.16 to 0.49. The estimates of displaced catch were <1 t and 8.8 t, equating to displacements of 4.3% and 34.0%, respectively (Table 1).

Targeted effort for snapper also declined significantly from 2008/09 onwards, dropping to the lowest recorded level in 2013/14 (Fig. 8). The annual estimates of the proportions of targeted effort expended during the 'reference' period were relatively consistent up to 2011/12 ranging from 0.18 to 0.27, but increased to 0.41 in 2012/13. Estimated displaced effort using the two methods were 0 and 81 mandays, with the latter equating to a displacement of 20.8% (Table 1).

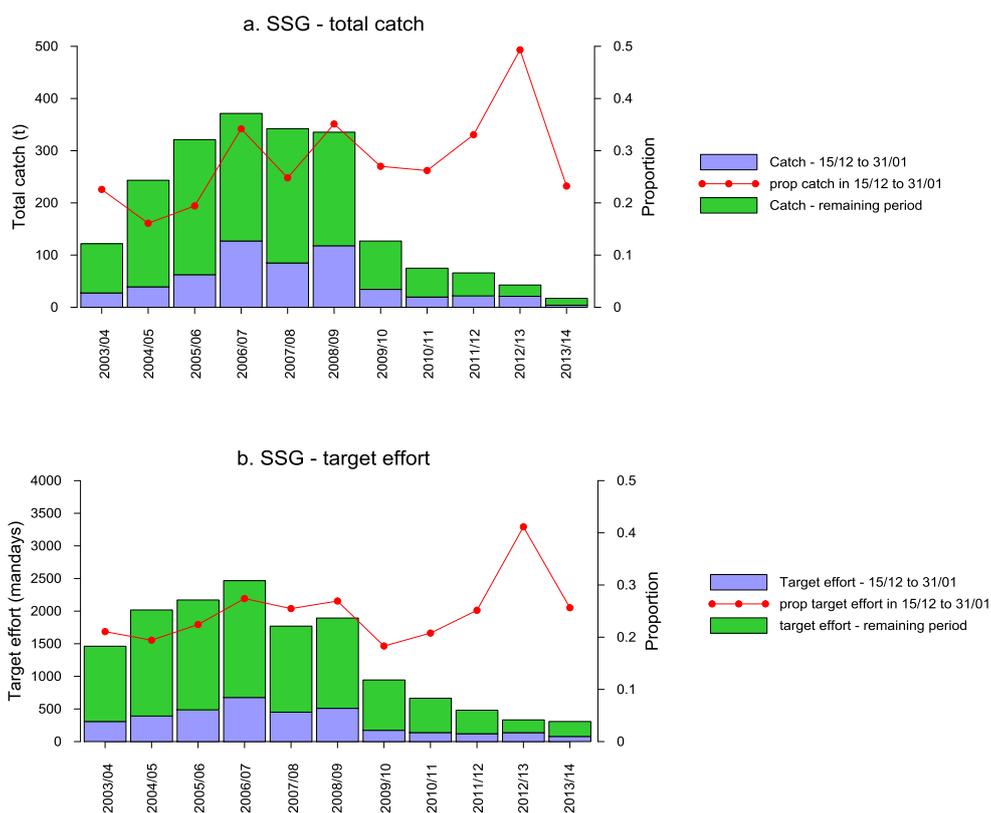


Fig. 8. Southern Spencer Gulf. a. Historical record of total commercial catch of snapper across all gear types, differentiating catch taken in the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual catch taken during the 'reference' period. b. Historical record of the commercial targeted effort across all gear types directed at snapper, differentiating effort expended in the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual targeted effort expended during the 'reference' period each year.

Northern Gulf St. Vincent

Total annual catch increased in this region particularly after 2008/09, reaching record high levels between 2009/10 and 2013/14 (Fig. 9). The proportion of catch taken during the reference period ranged from 0.1 to 0.2, and did not show the same significant increase in 2012/13 that was evident for both NSG and SSG. Nevertheless, for consistency, the same two methods used for the two Spencer Gulf regions were used to calculate displaced catch. Whilst Method (1), indicated no displaced catch, Method (2) produced a displaced catch of 5.5 t, representing a moderate reduction of 1.3% (Table 1).

Targeted effort also increased significantly in NGSV after 2008/09 (Fig. 9). The comparison across years of the proportion of targeted effort expended during the reference period ranged from 0.1 to 0.22, with the highest recent value being recorded in 2012/13. Estimates of displaced effort were from 0 to 130 mandays, with the latter reflecting a reduction of 4.2% (Table 1).

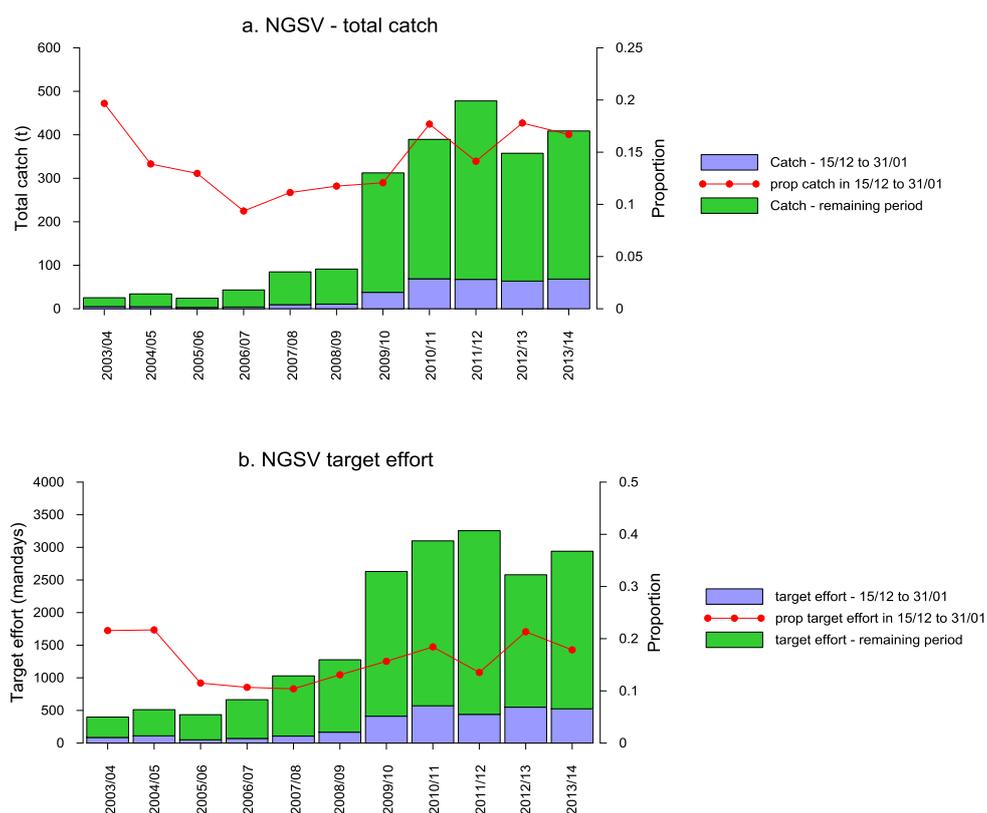


Fig. 9. Northern Gulf St. Vincent a. Historical record of total commercial catch of snapper across all gear types, differentiating catch taken in the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual catch taken during the 'reference' period. b. Historical record of the commercial targeted effort across all gear types directed at snapper, differentiating effort expended in the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual targeted effort expended during the 'reference' period each year.

Estimation of displaced catch and effort for the charter boat sector

Northern Spencer Gulf

Annual charter boat catch was similar from 2007/08 to 2011/12, but then declined considerably over the following two years (Fig. 10). The proportion of total annual catch taken during the reference period was consistent across years ranging from 0.23 to 0.28. Given this lack of variability, a single estimate of displaced catch in 2013/14 was calculated using the average value of P_{ref} from across the earlier years of 2007/08 to 2012/13. The estimated displaced catch was 180 kg, a reduction of 1.1% (Table 2).

Annual charter boat effort targeted on snapper in NSG also declined in 2012/13 and then again in 2013/14 (Fig. 10). The proportion of effort expended in the reference period was relatively consistent across years, ranging from 0.18 to 0.26. The estimated displaced effort due to the snapper spatial spawning closure was 0 days (Table 2).

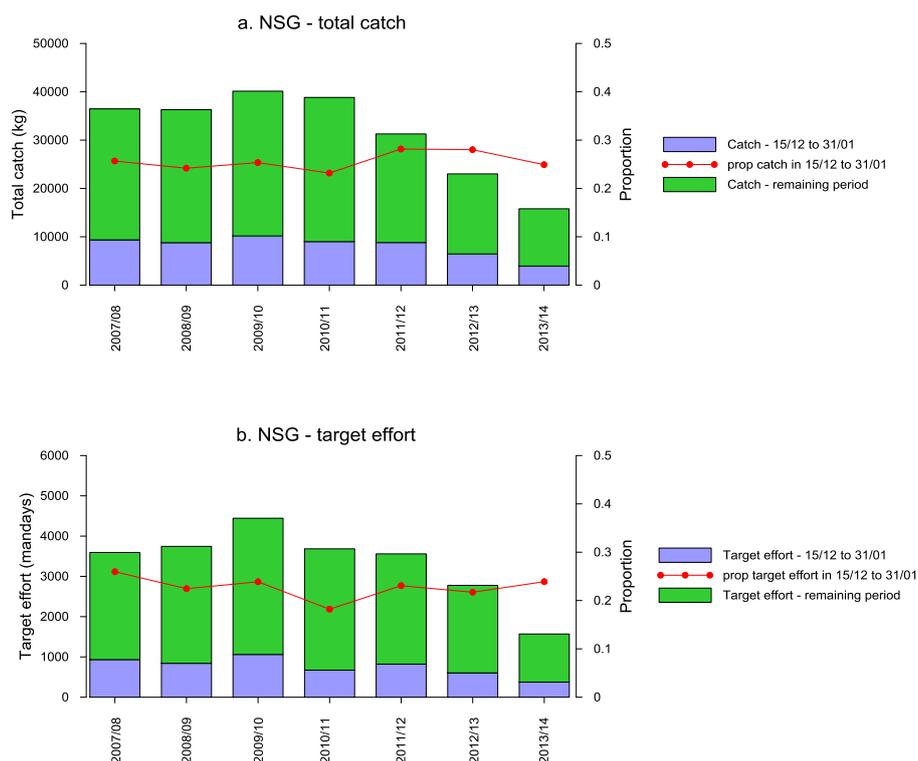


Fig. 10. Northern Spencer Gulf a. Historical record of total charter boat catch of snapper, differentiating catch taken during the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual catch taken during the 'reference' period. b. Historical record of the targeted effort by the charter boat sector directed at snapper, differentiating effort expended during the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual targeted effort expended during the 'reference' period each year.

Southern Spencer Gulf

Total annual charter boat catch declined in 2012/13 and again in 2013/14 (Fig. 11). Nevertheless, the proportion taken during the reference period annually was consistent and relatively high at 0.4 to 0.5. There was also a considerable reduction in targeted effort in 2013/14. Nevertheless, the estimates of displaced catch and effort for the charter boat sector attributable to the snapper spatial spawning closures were zero (Table 2).

Table 2. Summary of regional estimates of displaced total catch and targeted effort on snapper for South Australia's charter boat fishery, attributable to the introduction of spawning spatial closures in 2013/14.

Region	Displaced catch (kg)	Displaced targeted effort (method 1) (mandays)
NSG	180 (1.1%)	0 (0%)
SSG	0 (0%)	0 (0%)
NGSV	0 (0%)	0 (0%)

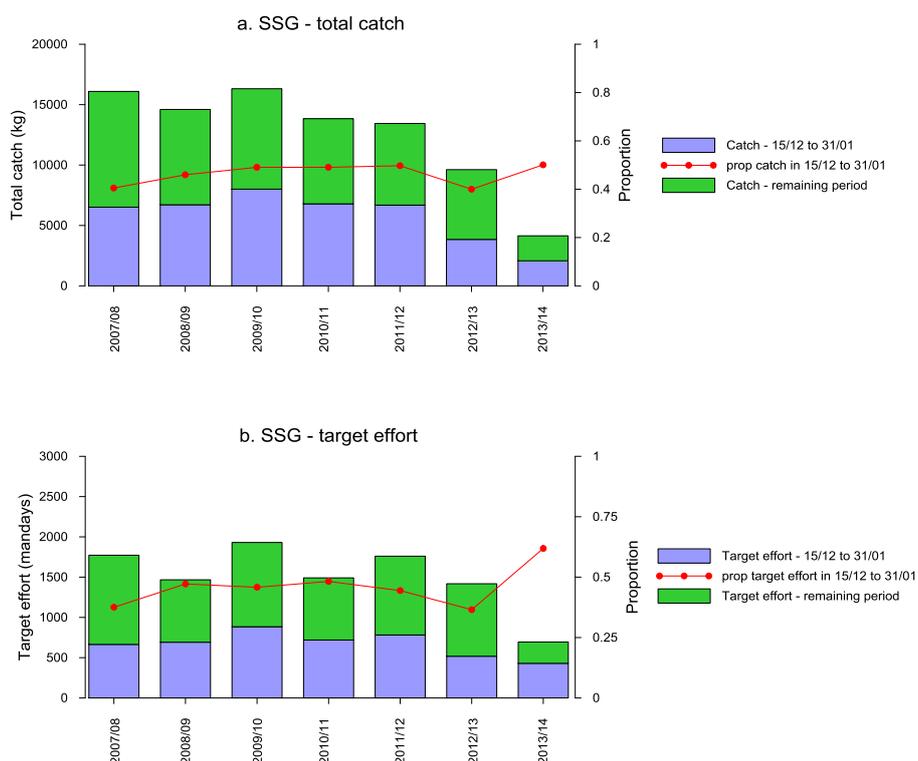


Fig. 11. Southern Spencer Gulf a. Historical record of total charter boat catch of snapper, differentiating catch taken during the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual catch taken during the 'reference' period. b. Historical record of the targeted effort by the charter boat sector directed at snapper, differentiating effort expended during the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual targeted effort expended during the 'reference' period each year.

Northern Gulf St. Vincent

Charter boat catches increased dramatically subsequent to the low values taken in 2007/08 and 2008/09 (Fig. 12). The proportions taken during the reference periods were quite variable, ranging from 0.05 to 0.5, but with no long-term trend. The estimated displaced catch from this sector in 2013/14 was zero (Table 2). Targeted effort varied in a similar pattern to total catch, and the proportion expended in the reference period each year ranged from 0.12 to 0.43. The estimated displaced effort was also estimated at zero (Table 2).

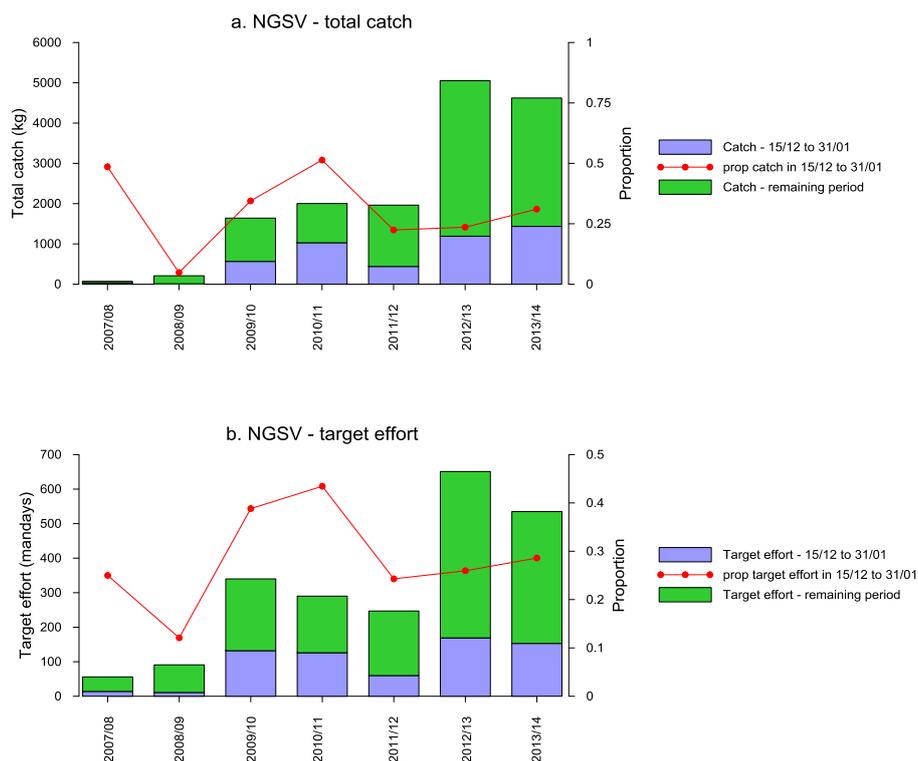


Fig. 12. Northern Gulf St. Vincent a. Historical record of total charter boat catch of snapper, differentiating catch taken during the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual catch taken during the 'reference' period. b. Historical record of the targeted effort by the charter boat sector directed at snapper, differentiating effort expended during the 'reference' and 'remaining' periods of each year. Also shown is the proportion of annual targeted effort expended during the 'reference' period each year.

Snapper egg survey

Plankton sampling was done throughout NSG from 11 to 15 December 2013, during which a total of 191 stations were sampled (Fig. 13). The kernel density map showing the relative abundances of the 'possible' snapper eggs indicates a number of hot spots. In the southern part of NSG, the hot spots corresponded directly with the sites of the two spawning spatial closures at the Estelle Star and Jurassic Park. The main hot spot located further north off Western Shoal lies to the north of the spawning closures located at the Illusion and the Santa Anna. The most northern hot spot for possible snapper eggs located off Point Lowly and Fitzgerald Bay was a considerable distance north of the spatial closures.

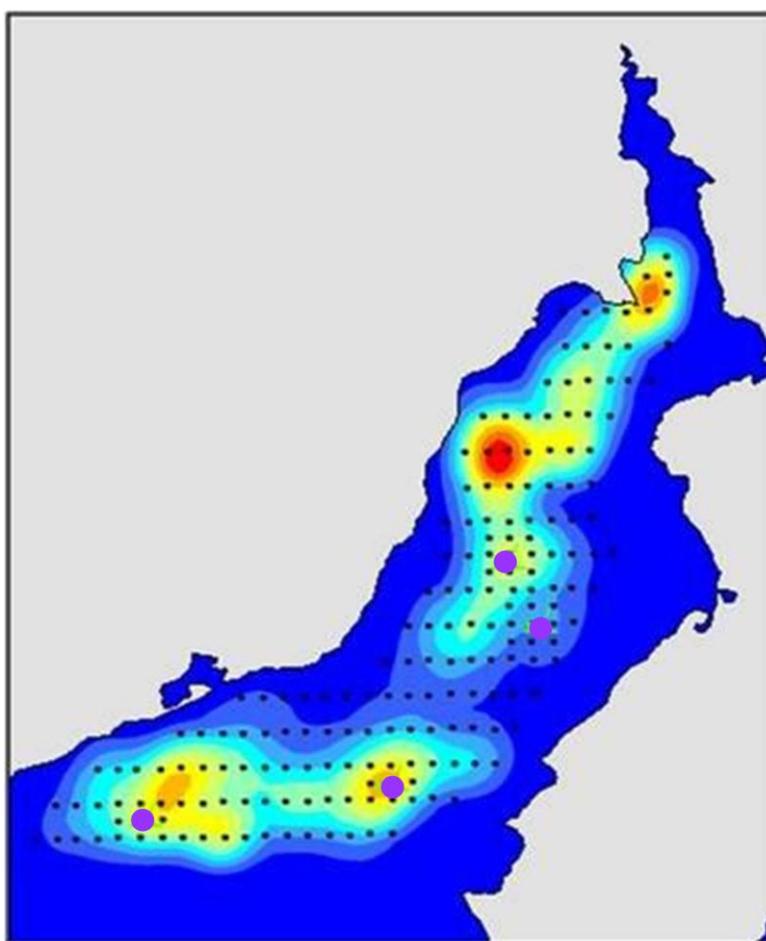


Fig. 13. Kernel density map showing the relative abundances of 'possible' snapper eggs throughout NSG, based on the plankton survey undertaken in December 2013. Sampling stations are indicated as black dots and locations of snapper spawning spatial closures as purple dots. Relative abundances increase with colour: low – blue to high – red.

DISCUSSION

The success of the snapper spawning spatial closures implemented in the northern gulfs of South Australia in 2013/14 in enhancing recruitment by providing opportunities for spawning without disturbance by fishing will not be known for several years. The current evaluation is limited to an assessment of the impacts of the spatial closures on catch and effort by the commercial and charter boat sectors, based on historical trends, as well as the preliminary data from the plankton survey in December 2013.

Northern and Southern Spencer Gulf

For both NSG and SSG, the trends in the commercial fishery statistics were similar. In both regions, the recent declining levels of commercial catch and effort, as well as significant declines in CPUE in 2012/13 and 2013/14, are consistent with continuing declines in the regional levels of biomass. Both regions were assigned the status of 'transitional depleting' in 2013 (Fowler et al. 2013), and the results presented here indicate that this status remained appropriate up to mid 2014.

The assessment of the impact of the snapper spawning spatial closures was done at a time when the biomass in both regions was low. Furthermore, there was the added complication that the extension of the seasonal closure to 15 December was first applied in 2012/13. This resulted in a change in the relative proportions of catch and effort taken or expended through the period of 15 December to 31 January, and indicated a concentration of fishing activity immediately following the reopening of the fishery on 15 December in 2013. In comparison between 2012/13 and 2013/14, catch and effort further declined marginally, but the proportional breakdown between the reference and remaining periods of the year, was considerably reduced. This suggests that the spawning spatial closures had an effect at the regional scale of reducing fishing effort through the reference period in 2013/14. These reductions in catch and effort were considerably higher in NSG than for SSG, which is consistent with the fact that the four closures were concentrated in NSG, with only minimal extension into SSG (Fig. 2).

For the charter boat sector the most obvious changes in both regions from 2007/08 onwards were the declines in catch and effort in both 2012/13 and 2013/14. Whilst it is uncertain why charter boat catch and effort declined in 2012/13, the declines in 2013/14 may well relate, at least partly, to the extension of the seasonal closure for this sector to 15 December in 2013. However, the annual comparison of the proportional breakdown of catch and effort in the

reference and remaining periods remained relatively consistent across years suggesting that there was minimal impact of the spawning spatial closures on this sector in these two regions.

Some uncertainty remains about the interpretation of the results from the snapper egg survey in NSG, because the identification of the eggs has not yet been confirmed. Nevertheless, the distribution pattern of possible snapper eggs suggests that the spatial closures have been appropriately located. Hot spots for possible snapper eggs were found at the Estelle Star and Jurassic Park, where spawning snapper were found during the egg survey. Furthermore, the significant hot spot of eggs located off Western Shoal could well relate to spawning activity at the Illusion and Santa Anna and the subsequent advection of eggs from those sites. The completion of this work will depend on developing a DNA marker that will confirm the identification of snapper eggs, which should be done during 2015.

Northern Gulf St. Vincent

For NGSV, the annual time series of commercial catch and effort statistics indicated that in recent years this region has supported the highest biomass since the recording of fishery statistics began. As such, the status of 'sustainable' that was assigned in 2013 remains appropriate (Fowler et al. 2013). Furthermore, there was minimal variation in the relative proportions of commercial catch and effort in the reference and remaining time periods over time, including 2013/14. Such data are consistent with the snapper spawning spatial closure in NGSV having had minimal impact on commercial catch and effort through the period of 15 December 2013 to 31 January 2014. The results for the charter boat sector also indicated a minimal influence of the spawning spatial closures on this sector in NGSV.

Conclusions

Overall, the most significant impacts of the spawning spatial closures were experienced in Spencer Gulf, particularly the northern region. This finding is consistent with: four of the five closures being located in this region; the tendency for snapper in this region to form spawning aggregations; and the low regional biomass. Collectively, these limited the opportunities for fishers to operate elsewhere. Given this, the lack of perceptible impact for the charter boat sector for this region is difficult to reconcile. Alternatively, in NGSV, snapper tend to be more dispersed and do not aggregate to the same extent as in NSG. This more dispersed spawning pattern, combined with the higher regional biomass, and that there was only a single spatial closure meant that there was considerable opportunity for commercial and charter boat fishers to target their effort and catch snapper outside the boundary of the single spatial closure.

The snapper spawning spatial closures have only been implemented during one reproductive season. At present it is too early to determine the benefits of this in terms of having enhanced recruitment in 2013/14. Snapper populations in South Australia are characterised by significant annual variability in recruitment rates, which relates to environmental impacts on the survivorship of the eggs and larvae (Fowler et al. 2013). Whilst some years are conducive to high survivorship, some are not. As such, to assist in the recovery of depleted populations, it is important that egg production is maximised in every year to ensure that there are sufficient eggs available to take advantage in those years when the environmental conditions are good for survival. Consequently, it may take numerous years for any benefits of the spawning spatial closures to be realised. A further opportunity to assess the placement of the spawning spatial closures in NGSV and NSG will be provided by further systematic plankton sampling regimes to be done during the summers of 2014/15 and 2015/16. Furthermore, the next opportunity for a comprehensive analysis of regional stock status for snapper will be provided in the next stock assessment that is due in mid-2016.

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