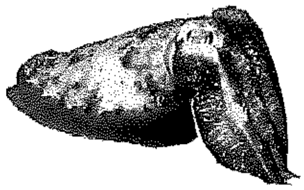
Estimated Abundance and Biomass of the Unique Spawning Aggregation of the Giant Australian Cuttlefish (*Sepia apama*) in Northern Spencer Gulf, South Australia.

MA Steer and KC Hall

September 2005

Report to Coastal Protection Branch, Department for Environment and Heritage, South Australia



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1.0. Executive Summary

1. This report provides an updated estimate of the total abundance and biomass of giant Australian cuttlefish (*Sepia apama*) in the unique spawning aggregation area in northern Spencer Gulf, South Australia. It also estimates the relative proportion of cuttlefish within three sub-areas of the aggregation area, i.e. "closed-closed", "closed-open" and "open-open" sub-areas, from 1998 to 2001 and 2005.

2. The cuttlefish population of the aggregation area in 2005 has declined in both abundance and biomass when compared to estimates for 2001, by 27.9% and 34.0%, respectively,

3. In the absence of any formal assessment from 2002 to 2004 it is difficult to determine whether the observed decline in 2005 is part of a downward trend, or a natural stock fluctuation.

4. Anecdotal evidence suggests that cuttlefish numbers were higher in 2005 than in 2004. This may suggest that the population is not steadily declining.

5. It is unlikely that the apparent decrease in cuttlefish spawning biomass in 2005 was a long-term consequence of increased exploitation from 1996 to 1998. It is possible, however, that illegal fishing during the peak spawning period, may have contributed to the observed decline.

6. Cephalopod populations are typically unstable and highly governed by environmental processes. It is therefore possible that in the absence of any significant fishing pressure the declines in estimates of abundance and biomass reflect natural variability in the actual population.

2.0. Introduction

Each winter tens of thousands of giant Australian cuttlefish (*Sepia apama*) aggregate on a discrete area of rocky reef in northern Spencer Gulf, South Australia, to spawn (Fig 1a, b). This is the only known dense aggregation of spawning cuttlefish in the world, and as such, has been identified as an area of national significance (Baker 2004). Historically, this aggregation supported a small, sustainable, bait fishery, where reported catches were generally less than 4 t per annum. However, in the mid-1990s, commercial fishing pressure significantly increased and by 1997 annual catch had increased to 250 t (Hall and McGlennon 1998). Such rapid exploitation was presumably in response to the potential for cuttlefish to develop into a profitable 'niche' market and had the capacity to further expand (Hall 2002a). Like other cephalopods, cuttlefish are short-lived and only experience one reproductive period at the end of their lives (Hall 2002a). Therefore, there is no accumulation of spawning biomass from one generation to the next and little buffer against years of poor recruitment or over-exploitation (O'Dor 1998). Consequently, the rapid expansion of the cuttlefish fishery raised considerable concern about the sustainability of the resource, particularly because fishers were targeting spawning animals, thus placing the population at a high risk of localised extinction. This concern was shared amongst other user-groups, including the recreational dive and eco-tourism sectors, and the film and television industry, which also relied on the unique spawning aggregation as a source of income (Hall 1999).

In 1998, a fishing closure that encompassed approximately 50% of the spawning area was implemented to ensure that a proportion of spawning animals were protected from fishing (Fig. 1c). As the fishing season progressed further concern was raised over the effectiveness of the partial closure, as fishing effort was shifted to other areas of the aggregation that were equally susceptible. Consequently, the closure was reviewed and expanded to include most of the main spawning grounds for the remainder of the season (Fig. 1d). For the subsequent five years (1999 to 2003) the main spawning grounds were closed to fishing for the duration of the entire spawning season, i.e. from 1st March until 30th September. In 2004, the closure was once again reviewed and amended to protect all cephalopods (including southern calamary *Sepioteuthis australis* and octopus) and to remain full-time, effective until 31st December 2006 (Fig. 1e).

SARDI monitored the abundance and biomass of spawning cuttlefish in the aggregation area annually from 1998 to 2001 as part of a stock assessment process (Hall and McGlennon 1998; Hall 1999; 2000; 2002b). These surveys also provided a significant opportunity to assess the effectiveness of the areal closures. After the completion of the FRDC-funded PhD study that was conducted through the period of 1998 to 2002 (Hall 2002a, Hall and Fowler 2003) there was no on-going monitoring program for cuttlefish at the aggregation site. Nevertheless, there were anecdotal reports particularly in 2004 that the numbers of cuttlefish in the aggregation were lower than in previous years (pers. com. Tony Bramley of Whyalla Diving Services). As such, the Coastal Protection Branch of South Australia's Department for Environment and Heritage commissioned SARDI to undertake a survey at the aggregation site in late May/early June 2005, the time when the numbers are at their highest. This report presents the results of that survey in the context of the results of previous fishery catches and surveys.

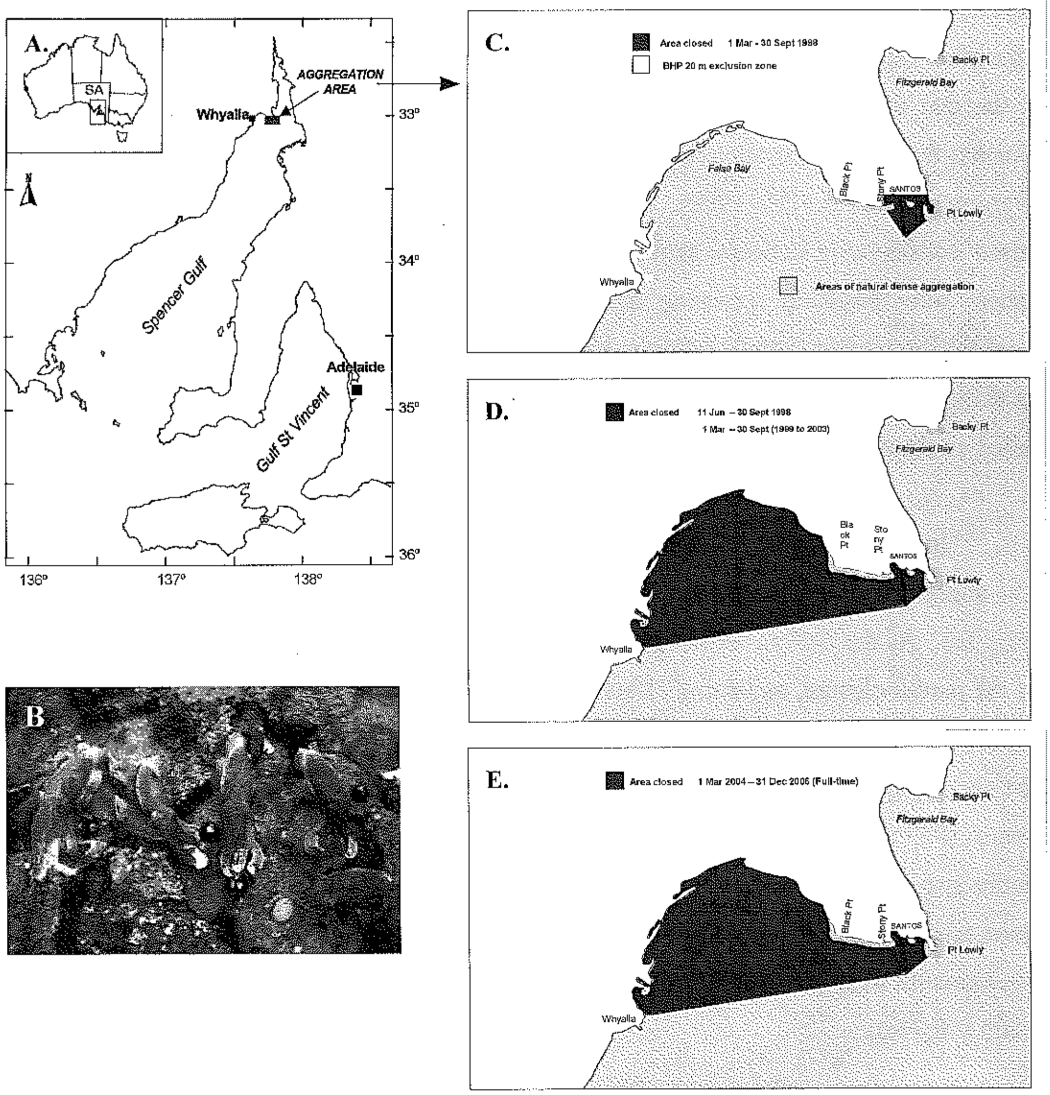

Figure 1. (a) Location of the cuttlefish aggregation site in northern Spencer Gulf, South Australia, (b) Spawning cuttlefish (photo courtesy of Dr. K. Hall), (c) Area of first fishing closure implemented at the beginning of the 1998 spawning season, (d) Reviewed closure mid-way through the 1998 spawning season, (e) Current full-time fishing closure, implemented in 2004 and effective until 31st December 2006.

3.0. Methods

The abundance and biomass of spawning cuttlefish were surveyed on 1st and 2nd June 2005 using the methodology established by Hall (2002a). As the fishing closure was amended over the years, the total aggregation area was partitioned into three sub-areas based on fishing history. These were: "closed-closed" area, i.e. the original closed area in 1998; "open-closed" area, i.e. the area that was subsequently closed half way through the 1998 season; and "open-open" area, i.e. the area that has always remained open to fishing (Fig. 2). Like the previous surveys done each year from 1998 to 2001, four 50 x 2 m belt-transects were completed at three to five sites within each area (Fig. 2). To efficiently use the limited time and resources three SCUBA divers systematically contributed to the survey, rather than a single diver, as in previous surveys. All cuttlefish encountered within the belt-transects were counted, their mantle length (ML) estimated to the nearest centimetre and their sex noted. This provided an estimate of the average density of cuttlefish per 100 m^2. An estimate of the average weight per 100 m^2 was also calculated by converting mantle lengths to weight using an appropriate length-weight relationship (Hall 2002a). To correct for any observer bias, each diver estimated the size and sex of 30 cuttlefish underwater, prior to the survey. Each animal was then individually captured, using a dip-net, and its length was measured at the surface. This provided a diver-specific correction factor that was incorporated into the weight conversions, thus improving their accuracy.

Abundance estimates were calculated for each site by multiplying the average density of cuttlefish per 100 m^2 by the corresponding area of spawning substrate. Estimates of area of available spawning substratum had been determined by Hall (2002a). Biomass estimates were calculated using the average weight of the cuttlefish per unit area. Total abundance and biomass of the entire aggregation area were extrapolated from site estimates. Commercial cuttlefish catch data from around the spawning aggregation (Marine Fishing Area 21) and the remainder of the State were obtained from the GARFIS database of the Fisheries Statistics Unit at SARDI (Aquatic Sciences). These data were included as they represented biomass that had potentially been removed from the "open-open" sub-area.

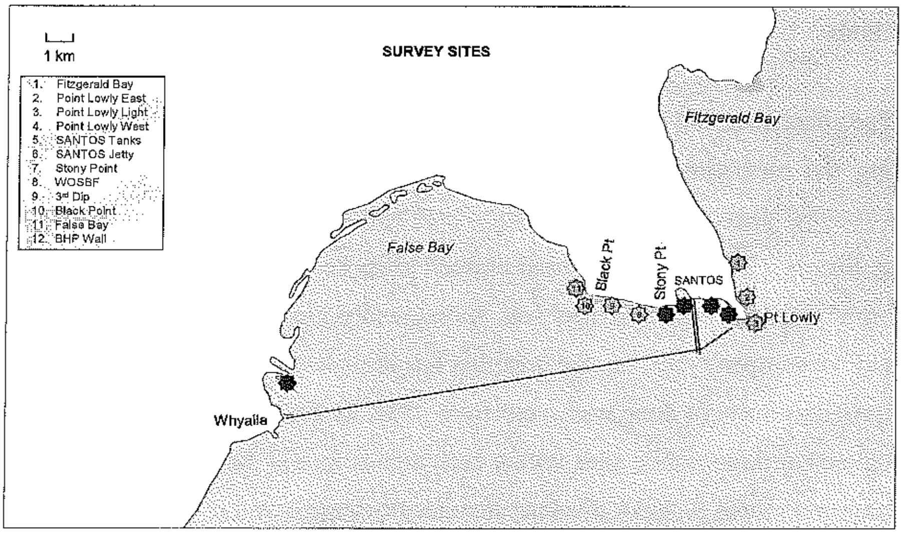

Figure 2. Location of survey sites in the False Bay area. Red stars depict "closed-closed" sites, orange stars depict "open-closed" sites and green stars depict "open-open" sites. Note; BHP Wall was not sampled in 2005 due to access restrictions.

4.0. Results

4.1. Abundance

The previous estimates of total abundance in early June in each year increased from 88,634 individuals in 1998 to over 170,000 in the following three years (1999-2001) (Table 1). Although this increase appears dramatic, it is not known what the level of abundance may have been during the beginning of the 1998 season had fishing not occurred. The estimates of cuttlefish abundance declined by 27.9% from 2001 to 2005 (Table 1.).

Table 1. Comparison of estimates of cuttlefish abundance from 1998 to 2001 and 2005 on the northern Spencer Gulf spawning aggregation during peak spawning (early June). Standard deviation of the mean is displayed in brackets. Note: there were no annual cuttlefish surveys from 2002 to 2004.

AREA	1998	1999	2000	2001	2005
Closed-closed	33,064 (± 7,375)	42,381 (± 20,170)	47,413 (± 7,353)	53,628 (± 10,191)	32,715 (± 15,260)
Open-closed	51,999 (± 11,685)	133,055 (± 27,704)	122,134 (± 35,747)	121,752 (± 18,679)	92,895 (± 20,165)
Open-open	3,570 (± 1,885)	7,205 (± 3,251)	1,559 (± 841)	1,782 (± 1,309)	2,175 (± 1,302)
Whole aggregation	88,634 (± 13,945)	182,642 (± 34,422)	171,106 (± 36,505)	177,161 (± 21,318)	127,785 (± 25,322)

4.2. Biomass

In 1997, prior to any management strategies and structured cuttlefish surveys, commercially targeted catch in the spawning area (MFA Block 21) was 244 t. With the implementation of the closure, commercial catch decreased to <14 t in 1999 and remained <19 t in subsequent years (Fig. 3). With the exception of 1997, targeted catch in the rest of the State has remained <1.0 t (Fig. 3). Biomass estimates in the "open-open" area remained relatively stable over the last three surveyed years. Estimates of total biomass obtained for 1998 to 2001 suggested that biomass was 18% lower in 2000 when compared to peak biomass in 1999, and remained at that level in 2001 (Table 2). In 2005, estimated biomass was 33.7% lower than that of 2001. There is a considerable uncertainty surrounding the biomass estimates, with standard deviations ranging from 15.1 to 25.9% of the mean (Fig. 4). This uncertainty arises from a number of different sources of error including those associated with habitat measurements, estimating cuttlefish length and sex *in situ*, and general sampling. As such, this variation must be considered when interpreting these trends.

Table 2. Comparison of estimates of cuttlefish biomass (t) from 1998 to 2001 and 2005 on the northern Spencer Gulf spawning aggregation during peak spawning (early June). Standard deviation of the mean is displayed in brackets. Note: there were no annual cuttlefish surveys from 2002 to 2004. * the amount of cuttlefish caught (t) from MFA Block 21, potentially from "open-open" sites. Data includes commercially targeted catch for the calendar year in 1997 and the main spawning season (from March to June) for all other years. Catch data for 2000 and 2005 are not included for confidentiality reasons, as fewer than five fishers were involved.

AREA	1997	1998	1999	2000	2001	2005
Closed-closed		39.1 (± 9.7)	51.3 (± 25.9)	44.7 (± 6.4)	51.1 (± 10.5)	27.7 (± 13.9)
Open-closed		55.8 (± 9.6)	158.9 (± 25.8)	133.0 (± 6.4)	130.5 (± 10.5)	92.1 (± 13.9)
Open-open		3.4 (± 1.7)	8.3 (± 3.5)	1.4 (± 0.5)	1.7 (± 0.5)	1.8 (± 0.3)
Whole aggregation	Not surveyed	98.2 (± 17.1)	218.5 (± 42.5)	179.1 (± 40.1)	183.3 (± 27.6)	121.6 (± 31.5)
Commercial* catch	244.4	109.0	3.7	n.a	1.0	n.a
Grand Total		207.2	222.2	179.1	184.3	121.6

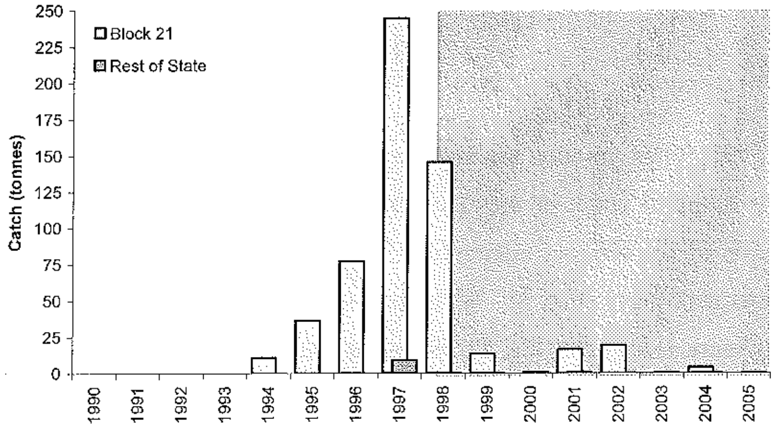

Figure 3. Annual commercially targeted cuttlefish catch for South Australia, comparing the catches from the main spawning area (MFA Block 21) and the rest of the State. The grey area indicates the period of fishery closure as described in Fig 1. Note: Data for Block 21 in 1990-1993, 2000, 2003 and 2005 were not included for confidentiality reasons as fewer than five fishers were involved.

The spatial distribution of cuttlefish biomass within the aggregation area changed over the survey years. In 1998, commercial catch accounted for approximately half of the estimated biomass, despite the main fishing region closing halfway through the season (Fig. 4). Catch was clearly much lower in subsequent years, due to the fishing closure.

The estimated biomass in the "closed-closed" area remained relatively stable throughout the survey years, accounting for 18.9 to 27.3% of the total biomass. Only one site in this sub-area, Stony Point, consistently supported a substantial biomass (Fig. 5). Following the closure of the adjacent area in late 1998, biomass increased at Stony Point from 25.1 t in 1998 to 42.8 t in 1999, representing a 70.5% increase over one season. Estimated biomass remained around 40t in 2000 and 2001, but declined to 24.5 t in 2005.

Estimated biomass in the "open-closed" area was greater than other areas combined. Biomass increased by 184% from 55.8 t in 1998 to 158.9 t in 1999 following the amended closure (Table 2). This increase was consistent across all sites (Fig. 5). The spatial distribution of biomass within the "open-closed" area changed little over the surveyed years. Black Point has consistently supported the greatest biomass in this area, even when the area was open to fishing, and was traditionally the site that was most heavily fished (Hall 2002b).

Estimated biomass in the "open-open" area was the lowest of the surveyed area. Biomass initially increased 144% from 3.4 t in 1998 to 8.3 t in 1999 following the closure and then markedly declined to <2.0 t in 2000 and remained at this level in all other surveyed years (Table 2). .

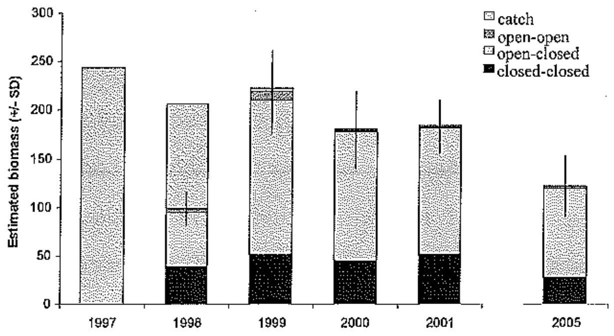

Figure 4. Annual estimates of total biomass (± Standard deviation) (t) partitioned into commercial catch and the three areas. Note: there were no annual cuttlefish surveys from 2002 to 2004.

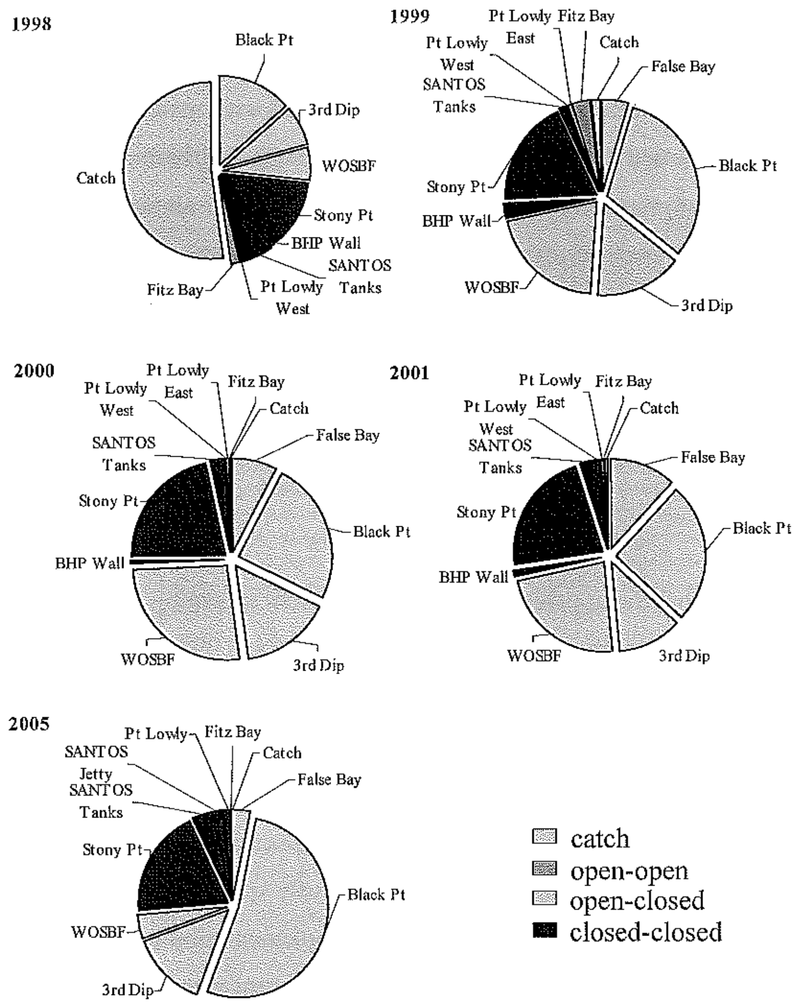

Figure 5. Breakdown (%) of the annual estimates of total biomass according to survey sites and commercial catch at the end of May in each year (1998-2001 and 2005). Note: False Bay and Point Lowly East were not surveyed in 1998, and BHP Wall was not surveyed in 2005 due to access restrictions.

5.0. Discussion

The current assessment suggests that the cuttlefish population of the aggregation area may have declined in both abundance and biomass when compared to the previous estimates in 1998 to 2001 and the reported catch in 1997. In the absence of any formal assessment from 2002 to 2004, it is difficult to determine whether this decline had been part of a systematic downward trend, or a result of natural fluctuation in population size due to variable recruitment. In contrast to these results, anecdotal evidence suggests that cuttlefish abundance had actually increased in 2005, signifying an end to a steady decline observed over the previous three years (pers. com. Tony Bramley). This turn-around was largely attributed to the amended closure in 2004, which provided year-round protection for cuttlefish within the aggregation area (pers. com. Tony Bramley).

Although 2005 estimates appeared lower than previous years, it should be noted that many different sources of error, including those associated with measurement and sampling methods, were incorporated into the estimates of abundance and biomass. Uncertainties in the estimates of total biomass were slightly greater than those for abundance due to the extra sources of measurement error involved in calculating cuttlefish weight from length estimates. Furthermore, an additional source of error was introduced in 2005 through using multiple divers, with minimal cuttlefish survey experience, instead of a single experienced diver as used in the past. The propagation of these uncertainties through serial calculations inherently reduced the precision of the population estimates and should be taken into consideration when interpreting trends.

It is unlikely that the apparent decrease in cuttlefish spawning biomass in 2005 was a long-term consequence of increased exploitation from 1996 to 1998. Like other cephalopods, cuttlefish are short-lived and the strength of one population critically depends on the strength and spawning success of the preceding generation. Therefore, if one generation is over-exploited it is expected that a significant population decline would be observed in the following season. Although over-exploitation may have serious short-term ramifications, in the longer term they should be able to recover relatively quickly, providing they have the appropriate level of protection (Caddy 1983). The implementation of the fishing closure in 1998 and its subsequent amendments has clearly protected the annual spawning aggregation, as reported commercial catch in the area (MFA Block 21) was markedly lower. State-wide fishing pressure had also declined, suggesting that the fishery had reverted back to the low level of exploitation seen in the early 1990s. Despite this level of protection and reduced fishing effort it appears that, biomass estimates have continued to decline. This suggests that there must be factors other than commercial fishing that are responsible for the trend. One possible explanation is continued illegal fishing. Although the main spawning area has been closed to both recreational and commercial fishing, there have been anecdotal reports of illegal fishing within the closure and during peak spawning periods. It is difficult to determine the level of illegal catch, as few data are available. Consequently, it is unknown what effect illegal fishing has on annual estimates of abundance and biomass.

Cephalopod populations are renowned for being unstable and capable of responding rapidly to changes in environmental conditions (Rodhouse 2001). As such, their abundance can fluctuate widely between generations. Species exhibiting a high degree of reproductive seasonality, such as the giant Australian cuttlefish, carry a major risk of recruitment failure should the hatchlings not coincide with optimum environmental conditions (Boyle and Rodhouse 2005). It is possible, that the reduction in cuttlefish abundance and biomass in 2005 simply reflects this natural variability, however further time-series monitoring, including environmental variables, is required before such conclusions can be made.

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Cuttlefish (*Sepia apama*)

Karina C Hall

University of Adelaide & SARDI Aquatic Sciences

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Fishery Assessment Report to PIRSA for the Marine Scalefish Fishery Management Committee

South Australian Fisheries Assessment Series 00/09

Cuttlefish (*Sepia apama*)

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Cuttlefish (*Sepia apama*)

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South Australian Fisheries Assessment Series 00/09

Cuttlefish (*Sepia apama*)

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Catch and effort data for the fishery were supplied by the commercial marine scalefish licence holders through the SARDI Aquatic Sciences Statistics Department.

Summer cuttlefish samples were obtained with assistance from the Spencer Gulf prawn trawl fleet and Tony Woods of Whyalla.

1. EXECUTIVE SUMMARY

1.1. Overview

This fourth stock assessment report for cuttlefish (*Sepia apama*) in South Australia reports on the biological and fishery indicators of the fishery and provides an assessment of its current status. The indicators currently being monitored for cuttlefish in South Australia are: a) the temporal and spatial variation in annual total catch, targeted fishing effort and catch rate in the commercial fishery; and b) estimates of the annual total abundance and biomass of cuttlefish at the main spawning grounds, derived by fisher-independent surveys.

The main commercial fishery for cuttlefish in South Australia is based on a localised spawning aggregation which occurs annually in the northern Spencer Gulf. For the past two years (1999 and 2000) the aggregation area has been closed to fishing for the duration of the spawning season (April – September). This has resulted in a decline in the total commercial catch of cuttlefish from 150 t in 1998 to 16 t in 1999 and 14 t in 2000. Previously the fishing block encompassing the aggregation area (Block 21) accounted for 92-98% of the total catch of the State. Even with the closure in place, in 2000, more than 80% of the targeted catch of cuttlefish was still taken from Block 21, possibly from areas adjacent to the closed area.

Fewer than 5 fishers targeted cuttlefish in 2000, which is over an 80% reduction since 1997 when no restrictions on the taking of cuttlefish were in place. Targeted effort declined from 535 fisher days in 1998 to 98 fisher days in 1999 and only 63 fisher days in 2000. The closure of the aggregation area to fishing during the spawning season has proved very effective in reducing both total catch and targeted effort in the commercial cuttlefish fishery.

The abundance and biomass of cuttlefish in the aggregation area has been monitored over the last three years (1998 – 2000) using underwater visual counts. The estimated total biomass was 218 t in 1998, 207 t in 1999 and 224 t in 2000. Although no monitoring was underway in 1997, the total commercial catch in the area was 235 t. These estimates suggest the biomass has changed little over the last three years, following the intense fishing effort exerted in the area in 1997. However, the temporal and spatial distribution of cuttlefish within the aggregation area has varied and some changes in the size structure of the spawning population are evident.

It is difficult to compare the results from commercial catch and effort data with those from visual surveys. Nevertheless, we consider that if our estimates of the past three years (1998 – 2000) are in error then they over-estimate the spawning biomass. This would suggest there has been a significant reduction in biomass since 1997. Unfortunately, the level of spawning biomass required to successfully spawn each year to sustain the population from year to year remains unknown.

The dramatic increases (150%) in the estimates of abundance and biomass in the previously fished area following closure of the area to fishing, suggest the vulnerability of the spawning aggregation to intense fishing effort even for short periods of time. In addition, individual licence holders have the potential to take very large catches, so limiting the number of licence holders alone, would be unlikely to reduce the overall catch.

The biological study in 2000 included an analysis of some size frequency distributions. This produced results for size modes of animals for particular times of the year that were incompatible with a population consisting of a single year class. Consequently, it is now evident that the population consists of several year classes. Such a population would respond differently to an intensive fishing regime than would a single year class fishery. This needs to be considered when formulating management policy.

1.2. Summary fishery statistics

Table 1a. Comparison of total catch, targeted catch and effort for entire State (1997 – 2000). (2000 data to June only).

Year	Total Catch		Targeted Catch & Effort		
	Catch (tonnes)	No. of Fishers	Catch (tonnes)	Effort (fisher days)	No. of Fishers
1997 - Unrestricted	262	63	253	919	33
1998 – Main area closed early	150	58	146	535	30
1999 – Main area closed all season	16	39	14	98	10
2000 – Main area closed all season	14	32	10	63	6

Table 1b. Comparison of total catch, targeted catch and effort for Block 21 (1997 – 2000). (2000 data to June only).

Year	Total Catch			Targeted Catch & Effort			
	Catch (tonnes)	No. of Fishers	% of Statewide Total Catch	Catch (tonnes)	Effort (fisher days)	No. of Fishers	% of Statewide Targeted Catch
1997 - Unrestricted	241	28	92%	235	841	28	93%
1998 – Main area closed early	146	25	98%	145	519	24	100%
1999 – Main area closed all season	14	9	84%	13	85	7	99%
2000 – Main area closed all season	N/A*	<5	N/A*	N/A*	N/A*	<5	N/A*

* Data for 2000 could not be included for confidentiality reasons, as fewer than 5 fishers were involved.

1.3. Biological indicators

Table 2a. Comparison of estimates of abundance for the last three spawning seasons (1998 - 2000).

Area	1998	1999	2000
TOTAL CLOSED AREA % estimated TOTAL ABUNDANCE	49,399 42%	53,797 25%	66,795 31%
TOTAL FISHED AREA % estimated TOTAL ABUNDANCE	67,700 58%	162,284 75%	148,667 69%
TOTAL Whole aggregation area	117,099	216,081	215,462

Table 2b. Comparison of estimates of biomass for the last three spawning seasons (1998 - 2000).

Area	1998	1999	2000
TOTAL CLOSED AREA % of estimated TOTAL BIOMASS	49 22%	50 24%	68 30%
TOTAL FISHED AREA % of estimated TOTAL BIOMASS	60 28%	152 74%	154 69%
TOTAL Whole aggregation area	109	203	222
CUMULATIVE CATCH (Block 21) Biomass removed from FISHED AREA	109 50%	4* 2%	2* 1%
GRAND TOTAL Whole aggregation area	218	207	224

* Amount removed as catch from Block 21 in 1999 and 2000 – potentially from Fitzgerald Bay and the BHP Wall at Whyalla.

1.4. Resource users

Table 3a. Resource users – Commercial fishery sector. (2000 data to June only).

Year	Number Fishers	Total Catch	Value *
1997 - Unrestricted	63	262 t	$333,200
1998 – Main area closed early	58	150 t	$193,400
1999 – Main area closed all season	39	16 t	$24,019
2000 – Main area closed all season	32	14 t	$23,077

* Value estimates based on average monthly prices paid by processors to fishermen.

Table 3b. Resource users – Processing and export sector. (2000 data to June only).

Year	Number Processors	Value *
1997 - Unrestricted	9	$130,000
1998 – Main area closed early	8	$75,000
1999 – Main area closed all season	<5	$8,200
2000 – Main area closed all season	<5	$7,200

* Value estimates based on $0.50 profit made per kg of cuttlefish caught.

Table 3c. Resource users – Recreational diving and tourism sector. Estimates provided by Tony Bramley of Whyalla Diving Services.

Year		Number of Visitors	Number of Dives	Itemised Value	Total Value
1997	- Non-local visitors - Local			$8,000 $10,000	$18,000
1998	- Non-local visitors - Local - Scientific (expenditure) - Film crews (expenditure)	112 5* 3		$12,000 $6,000 $8,000* $18,000	$44,000
1999	- Non-local visitors (directly as result of cuttlefish) - Local - Scientific (expenditure) - Film crews (expenditure)	420 11* 2	1,260 900 133* 150	$55,000 $12,000 $11,000* $36,000	$114,000
2000	- Non-local visitors (directly as result of cuttlefish) - Local - Scientific (expenditure) - Film crews (expenditure)	670 90 11* 10	3,500 1,000 142* 220	$180,000 $30,000 $20,000* $80,000	$310,000

*Estimates calculated from SARDI field logbooks and expense records.

NB: In the 1999 stock assessment report 1997 and 1999 data were erroneously reversed.

Table 3d. Resource users – Other sectors - 2000

Sector		Numbers	Value	Details
Recreational fishermen		No data	No data	
Scientific Interest	- Australian - International	9 2	Non-profit	Graduate students & scientists Collaborative Projects
Film/Television Industry		4	$10,000* $100,000* $1,000,000*	Sequence of footage sold locally Whole program distributed locally Major feature distributed world-wide
Public Interest		262,000	Non-profit	Number hits on "Cuttlefish Capital" Internet Site (Jun 1999 – Nov 2000)

* Value estimates from Glen Carruthers, Green Cape Wildlife Films (filmed cuttlefish in 1999 and 2000).

2. BACKGROUND

2.1. Description of the fishery

The main fishery targeting cuttlefish in South Australia has historically been based on the annual spawning aggregation of *Sepia apama* in the waters adjacent to Black Point and Point Lowly (henceforth referred to as the aggregation area) in northern Spencer Gulf (occurs within Fishing Block 21). The area covers approximately 8 km of coastline, and the cuttlefish occur in less than 8 m of water over the inshore rocky reef habitat. The majority of the catch is taken between May and July when thousands of cuttlefish aggregate in the area to spawn.

Cuttlefish are targeted using lines and squid jigs in the shallow inshore waters (< 200 m offshore). Vessels used in the fishery are generally the multi-purpose ones used for other marine scalefish fishing, typically 5-8 m in length. Up to 4-5 fishers operate from the one vessel. The use of larger sleeping vessels in combination with smaller dinghies was observed in the 1998 season.

Only small catches of cuttlefish are targeted throughout other areas of the State. Most of the catch taken outside the aggregation area is taken as by-catch by squid jigs and lines, and in haul nets, gill nets and rock lobster pots. An unquantified by-catch of cuttlefish is also taken by the Spencer Gulf and Gulf St Vincent prawn fisheries, however the amount is thought to be small and none of the catch is kept (Carrick 1999, pers. comm.).

Recreational fishers rarely target cuttlefish and they are usually only taken as by-catch by anglers who are targeting southern calamary (*Sepioteuthis australis*), as both species are caught using similar lines and jigs (McGlennon and Hall 1997).

2.2. Management

The commercial cuttlefish fishery in South Australia is currently managed under the broad management framework of the commercial marine scalefish fishery. Before 1998, there were no specific management controls in place for the taking of this species. Prior to the start of the 1998 fishing season, a time and area closure within the main spawning ground was introduced, in an attempt to protect some of the spawning population in the aggregation area. From 1 March 1998 to 30 September 1998, it was unlawful for any person to engage in any fishing activity within Spencer Gulf waters enclosed by the following boundaries:

> from the Point Lowly lighthouse to the southern end of the Port Bonython jetty, then to the seaward end of the western boundary fence of the SANTOS facility, and from there following the high water mark eastwards along the shoreline back to the lighthouse (Fig. 1).

This closure was found to cover approximately 44% of the reef habitat in the aggregation area (Hall and McGlennon 1998).

During the 1998 fishing season, concerns were raised regarding the level of spawning biomass protected by this closed area. In addition, an increase in fishing effort in the open area was observed. Consequently, the entire aggregation area was closed to fishing from 11 June until 30 September 1998:

> the taking of cuttlefish was banned in all waters of the Spencer Gulf enclosed by a line from the lighthouse at Point Lowly to the southern end of the Port Bonython jetty, then in a south westerly direction to the southern end of the BHP wall near Whyalla then follow high water

mark along the shoreline in an easterly direction to the point of commencement at the lighthouse (Fig. 1).

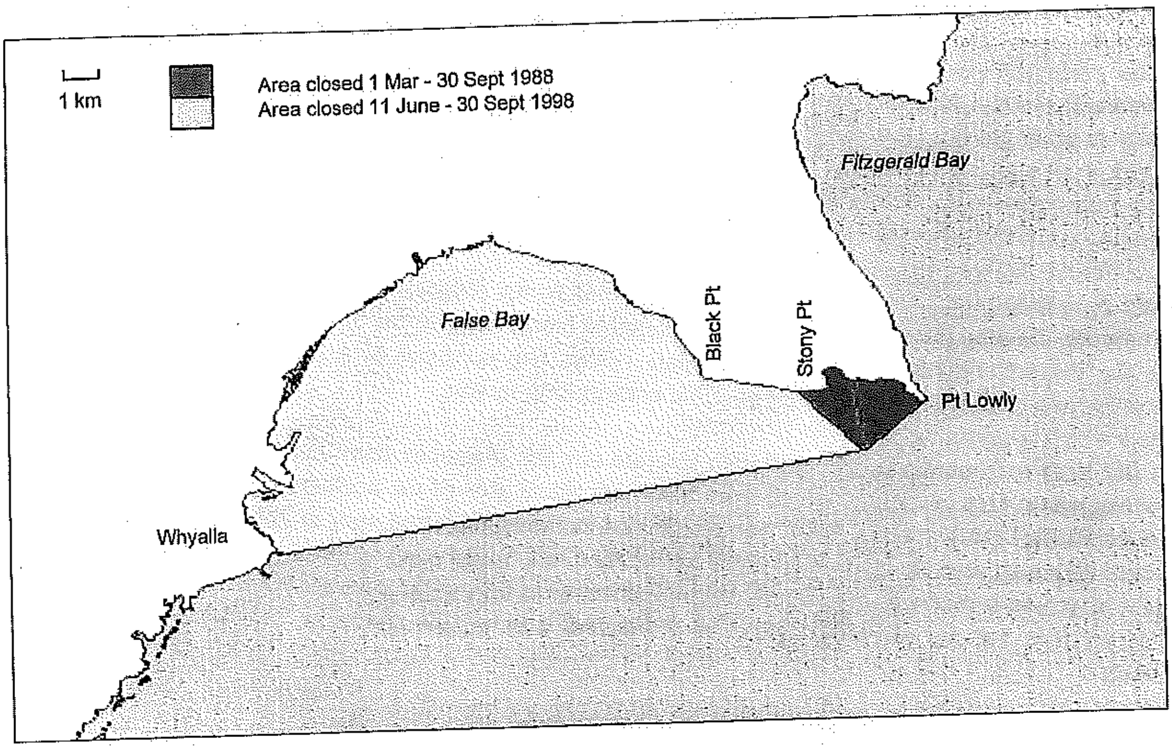


Figure 1. Map detailing the original area closed to cuttlefish fishing in 1998 (1 Mar – 30 Sept) and the subsequent area closed to fishing (11 June – 30 Sept) in northern Spencer Gulf near Whyalla.

A recreational limit of 15 cuttlefish per person, and 45 per vessel was also introduced in June 1998, at the time the main spawning grounds were closed.

In both 1999 and 2000, the main spawning grounds remained closed to fishing for the duration of the spawning season, i.e. from 1 March until 30 September in both years. However, the recreational limit was removed for all other areas of the State prior to the start of the 1999 season.

Management for the fishery for the 2001 season will be decided following a review of the 2000 stock assessment process.

2.3. Biology of *Sepia apama*

Very little is known about the biology of *Sepia apama*, even though it is the largest and most common cuttlefish species in southern Australian waters (Wadley and Dunning 1998), and one of the largest cuttlefish species in the world. It is endemic to Australia, with a distribution extending across southern Australia, from Ningaloo in Western Australia to Moreton Bay in southern Queensland, and including northern Tasmania (Lu 1998a).

A summary of the first two years of research on the biology of *S. apama* in South Australia is given below, with reference to the general biology of more extensively studied cuttlefish species where necessary.

Life-cycle

Most cuttlefish species display a migratory life-cycle, with adult feeding grounds in a different habitat/location to spawning grounds and juvenile feeding grounds (Boletzky 1983). The timing of sexual maturation and subsequent migration to spawning grounds appears to be linked to changes in water temperature and/or day length, and varies across the distribution of a species according to local conditions.

S. apama displays a similar migratory life-cycle in northern Spencer Gulf (Fig. 2). Numbers also increase in other coastal areas during winter months (May to August) when spawning occurs (Gales *et al.* 1993, Rowlings 1994, Nute A. 1998, pers. comm.). Some variation to this general winter spawning period may exist, e.g. mature specimens have been collected from Gulf St. Vincent in spring, suggesting some out-of-season spawning for that Gulf.

Female *S. apama* attach their eggs to the underside of rocks, ledges, caves and crevices in subtidal reef habitats (Moran 1998). The necessity for suitable hard substrate for the attachment of eggs may drive the inshore migration for spawning (Hall 1998). The presence of a suitable prey species or habitat for juveniles may also be other possible contributing factors.

It is not known from where the cuttlefish migrate nor the distances travelled to reach the inshore spawning areas. One cuttlefish tagged from the Plank Shoal area of the northern Spencer Gulf (60km south of Black Point) in April 2000 was recaptured in the aggregation area in June 2000 suggesting the cuttlefish may migrate from other areas within the Gulf. Widely but sparsely distributed adults are caught by prawn trawlers throughout northern Spencer Gulf during the summer (Carrick unpub. data). These animals are not sexually mature and frequently have full stomachs indicating they were feeding.

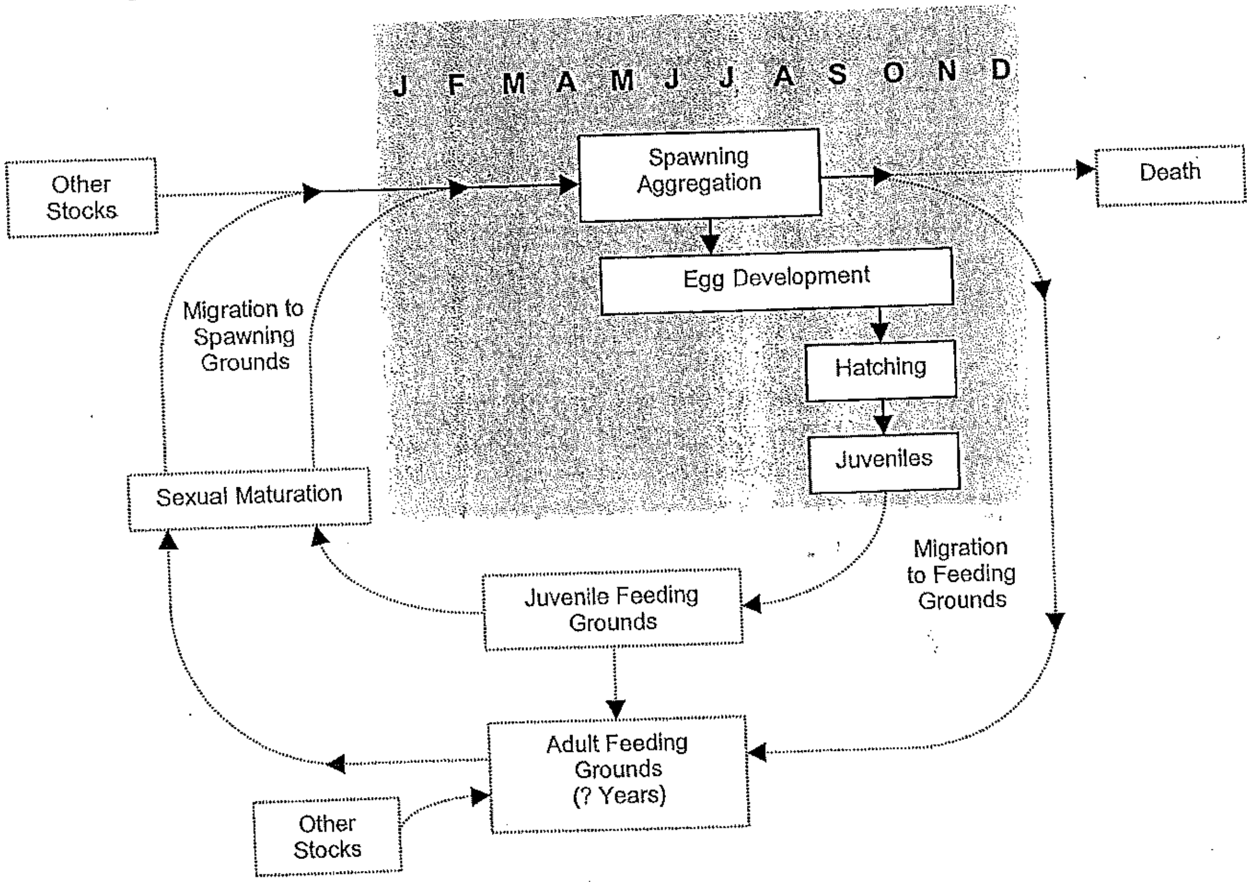


Figure 2. Schematic representation of the possible phases of the life-cycle of Sepia apama spawned in the aggregation area. The shaded area represents known phases of the life-cycle that occur in the aggregation area, the timing of which is indicated in the calendar above. Dashed lines represent other proposed life-history processes and stages.

Population structure

The population structure of *S. apama* in southern Australian waters is not known. The spawning aggregation in the Black Point to Point Lowly area appears to be the only one to occur across the distribution of the species. The unique mating system described for the spawning aggregation (Hall and Hanlon unpub. data), suggests it might constitute a population that is reproductively isolated from other populations in South Australian waters.

Reproductive biology

Female *S. apama* spawn large (11-18 mm diameter), yolky eggs which are encased in a gelatinous protective casing and laid individually. The size of mature eggs is proportional to the size of the female (Hall and McGlennon 1998). Larger females also possess larger ovaries, suggesting they may have greater reproductive output potential than smaller ones.

Fecundity is difficult to estimate for cuttlefish, but is considered to be relatively low (in the order of 100 to 1,000) compared to broadcast spawners like many fish species (Boyle 1990). The reproductive system of female *S. apama* consists of a single ovary, where eggs develop, and an oviduct, where fully developed eggs accumulate until spawning occurs. Within the ovary a wide range of developmental stages of eggs occur, even when there are fully developed eggs present in the oviduct. Therefore, it may be possible for females to spawn more than one batch of eggs in a season, and possibly over an extended period of time (perhaps the entire spawning season). It is not yet known how many undeveloped eggs in the ovary actually fully develop during the spawning season and over what time period an individual female may keep spawning. It does, however, suggest a prolonged spawning strategy for this species (Hall and McGlennon 1998). In support of this, tagged females were resighted in the aggregation area six weeks after being tagged.

Size and age structure

The size and age at sexual maturity and potential longevity for any given species of cephalopod is strongly influenced by temperature (Forsythe and Hanlon 1988). Animals reared at higher temperatures (even 5°C higher), tend to grow faster, reach larger sizes, mature younger and have shorter life spans than conspecifics reared at lower temperatures.

A range of size classes of males and females were recorded within the spawning population despite that this is thought to be an annually spawning, semelparous species. This reproductive strategy usually results in a population consisting of one cohort with a single size mode. All animals were sexually mature and potentially spawning. Either the different size classes represent individuals from the one stock maturing at different ages (Fig. 3a); or similarly-aged individuals which have attained different sizes due to differences in feeding, temperature, physiology etc. during their growth and maturation periods (Fig. 3b); or individuals from different stocks which have different ages or growth patterns (Fig. 3c). For further discussion of the size structure of the population refer to Section 3.4. of this report.

The only ageing work completed on *S. apama* to date, used the simple method of measuring the diameter of the freshly dissected eye lens (Hall and McGlennon 1998). There were several modes in eye lens diameters from female and male specimens collected from Black Point. Although this method is rather crude, it suggests there could be more than one cohort or generation present in the spawning aggregation.

Longevity

The longevity of *S. apama* is not known, however, it is commonly thought to be semelparous (Gales *et al.* 1993, Anon. 1993). Large numbers of cuttlebones and carcasses wash up onto various beaches around South Australia and in other southern States during the late winter months, which is assumed to relate to mass mortality events following spawning (Lu 1998b). Semelparous cephalopod species commonly undergo a decline in condition during or following exhaustive spawning which ultimately results in death (Mangold 1987). However, no obvious decline in condition indices was detected for animals collected from the aggregation towards the end of the spawning season (Hall and McGlennon 1998).

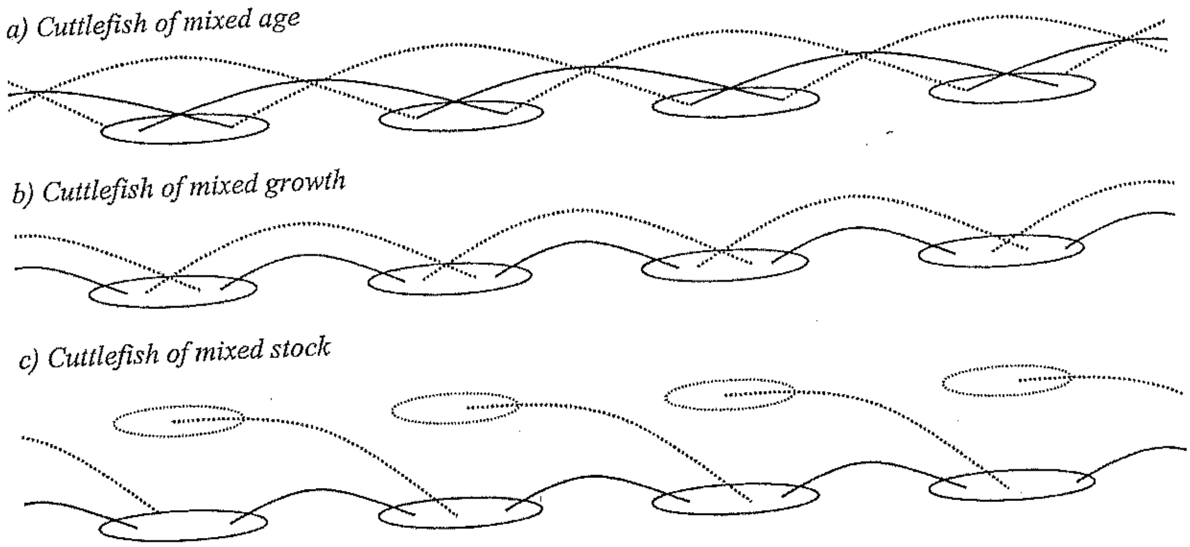


Figure 3. Diagrammatic representation of three alternative hypotheses to account for two size modes at maturity in an annually spawning, semelparous species. Annual spawning period is represented by the oval shape, solid lines indicate origin of small size mode, and dashed lines the origin of larger sized cuttlefish (original diagram proposed by Boyle *et al.* (1995) for squid *Loligo forbesi*).

Egg development and recruitment

There is no parental care of the eggs as most adult cuttlefish leave the spawning grounds before the first eggs fully develop.

The time taken for eggs to develop largely depends on water temperature (Hall and McGlennon 1998). Eggs laid at the start of winter take the longest time to develop (approximately 4 months) as most development takes place in cold water temperatures. Eggs laid towards the end of the season develop faster (approximately 2 months) due to increasing water temperatures. Hatching starts around the end of August and finishes around the end of October.

Field observations strongly suggest that sea urchins may eat or dislodge developing eggs. Urchins were often found underneath rocks surrounded by numerous stumps of eggs and some had partially consumed eggs in their mouth-parts. There are very high densities of urchins in the aggregation area which could impact on egg survival. Hatchlings were also preyed upon by small fish as soon as they emerged from their protective casings.

Little is known about the growth and movement of juveniles following hatching. Juveniles maintained in aquaria grew rapidly and fed voraciously on mysids and small rock pool shrimp (Hall unpub. data). Their growth rates in captivity suggest that juveniles spawned in one season may grow fast enough to reach maturity towards the end of the following season. However, they would only reach the smallest size classes observed in the spawning population (i.e. 10-15 cm mantle length).

3. CURRENT MONITORING AND RESEARCH

3.1. Overview

The biological and fishery indicators currently being monitored for cuttlefish in South Australia are:

- temporal and spatial variation in total catch, targeted fishing effort and catch rate (CPUE) in the commercial fishery;
- estimates of the annual total abundance and biomass of cuttlefish in the aggregation area derived from fisher-independent surveys;

3.2. Commercial fishery catch and effort

Catch

The historical total annual catch of cuttlefish (*Sepia apama*) taken by the commercial fishery in South Australia is shown in Fig. 4a. The total catch produced from Block 21 is also shown, as it accounts for most (70-98%) of the total catch of the State. Block 21 includes the aggregation area in northern Spencer Gulf where the main cuttlefish fishery operates.

Note that catch and effort data for this species refer to calendar years, in contrast to the general reporting of financial years. This is done to more accurately represent the main fishing season of April to July each year. For this reason, 2000 data only include catches to June. The total catch also includes non-targeted catch.

Total catch increased dramatically from 1993 to 1997 (fig 4a). In 1997, a peak catch of 262 t was reported, followed by a considerably smaller catch of 150 t in 1998 and then only 16 t in 1999 and 14 t in 2000. The sudden drop in catch reported over the last three years is attributable to the early closure of the main fishery in Block 21 during the second week of June in 1998, and the total closure of the main fishery for the duration of the spawning season in 1999 and 2000 (between 1 March to 30 September).

Effort

The trend in annual targeted fishing effort in the commercial fishery, shows a similar trend to that of total catch (Fig. 4b). Effort expressed as fisher days is calculated by multiplying the number of boat days recorded by each licence holder by the number of fishers operating from each vessel on any given day. Fishing effort increased from 1993 to a peak of 919 fisher days in 1997, then declined to 535 fisher days in 1998, 98 fisher days in 1999 and 63 fisher days in 2000. Therefore, there was minimal targeted effort on cuttlefish in the State over the last two years when the aggregation area has been closed to fishing.

CPUE

CPUE for Block 21 increased from 115 kg/fisher day in 1995 to a peak of 280 kg/fisher day recorded in both 1997 and 1998. CPUE then decreased by 40% to 159 kg/fisher day in 1999 and rose marginally in 2000 (exact data for 2000 could not be included for confidentiality reasons, as fewer than 5 fishers were involved) (Fig. 4c). The lower CPUE values recorded in 1999 and 2000 possibly reflect the presence of lower densities of cuttlefish outside the aggregation area. The slight increase in CPUE from 1999 to 2000 may indicate that higher densities of cuttlefish were present outside the aggregation area in 2000 or that the fishers had found alternative areas suitable for cuttlefish harvesting.

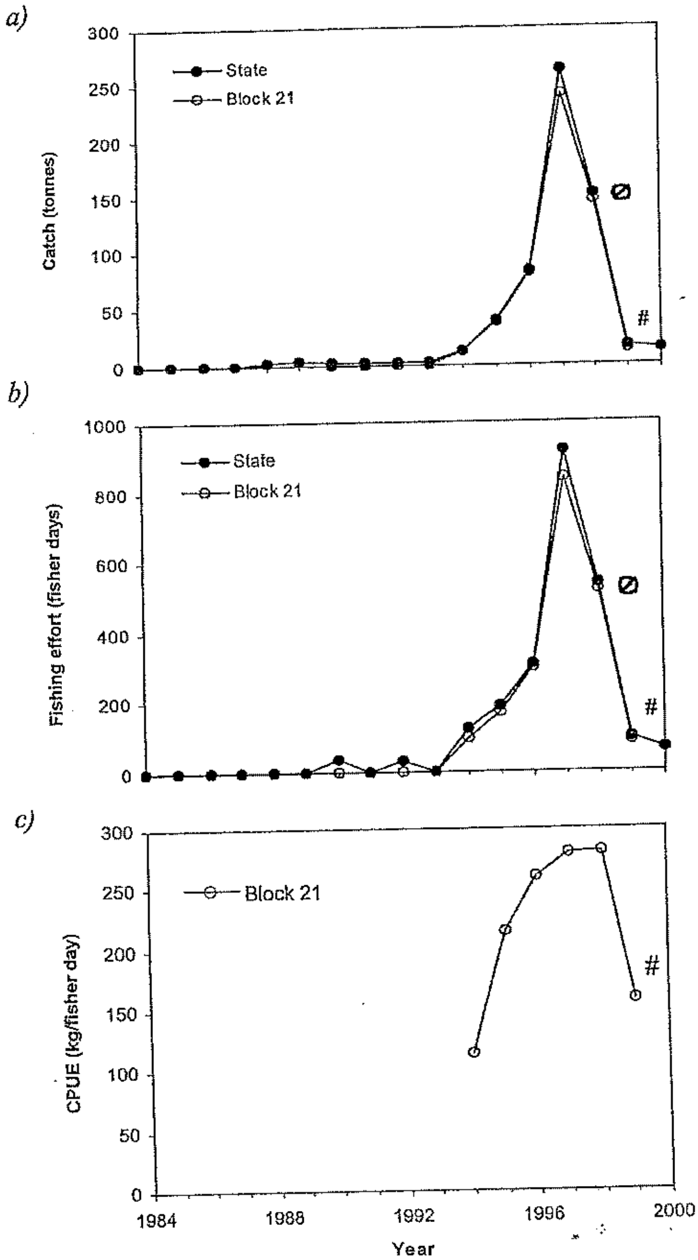


Figure 4. Annual total commercial catch *(a)*, targeted effort *(b)* and CPUE *(c)* of cuttlefish for South Australia and Block 21. The main fishery was closed early in 1998 (⊘) and all season in 1999 and 2000 (#). Data for Block 21 in 2000 could not be included in 2000 for confidentiality reasons as fewer than 5 fishers were involved.

Distribution of catch within State

The majority of the targeted catch for the State (90-100%) has been taken from Block 21 (Table 4). In 2000, >80% of the targeted catch of 10.7 t was taken from Block 21 even though the aggregation area was closed to fishing. This catch was presumably taken from other areas within Block 21 adjacent to the main spawning grounds. Other areas around the State where cuttlefish were targeted in 2000 and the general magnitude of catches reported are shown in Fig. 5.

Table 4. Comparison of total catch, targeted catch and number of licence holders for South Australia and Block 21 (2000 data to June only).

	Total Catch		Targeted Catch				
	State		State		Block 21		
Year	Catch (tonnes)	No. of Fishers	Catch (tonnes)	No. of Fishers	Catch (tonnes)	No. of Fishers	% of Statewide Targeted Catch
1994 - Unrestricted	12.4	34	11.0	14	10.9	8	99%
1995 - Unrestricted	39.9	38	36.6	15	36.3	10	99%
1996 - Unrestricted	82.6	48	77.3	15	77.2	13	100%
1997 - Unrestricted	262.1	63	253.5	33	235.5	28	93%
1998 - Closed early	150.2	58	145.9	30	145.5	24	100%
1999 - Not opened	16.5	39	13.6	10	13.5	7	99%
2000 - Not opened	14.4	32	10.7	6	N/A	<5	>80%

* Block 21 data for 2000 could not be included for confidentiality reasons, as fewer than 5 fishers were involved.

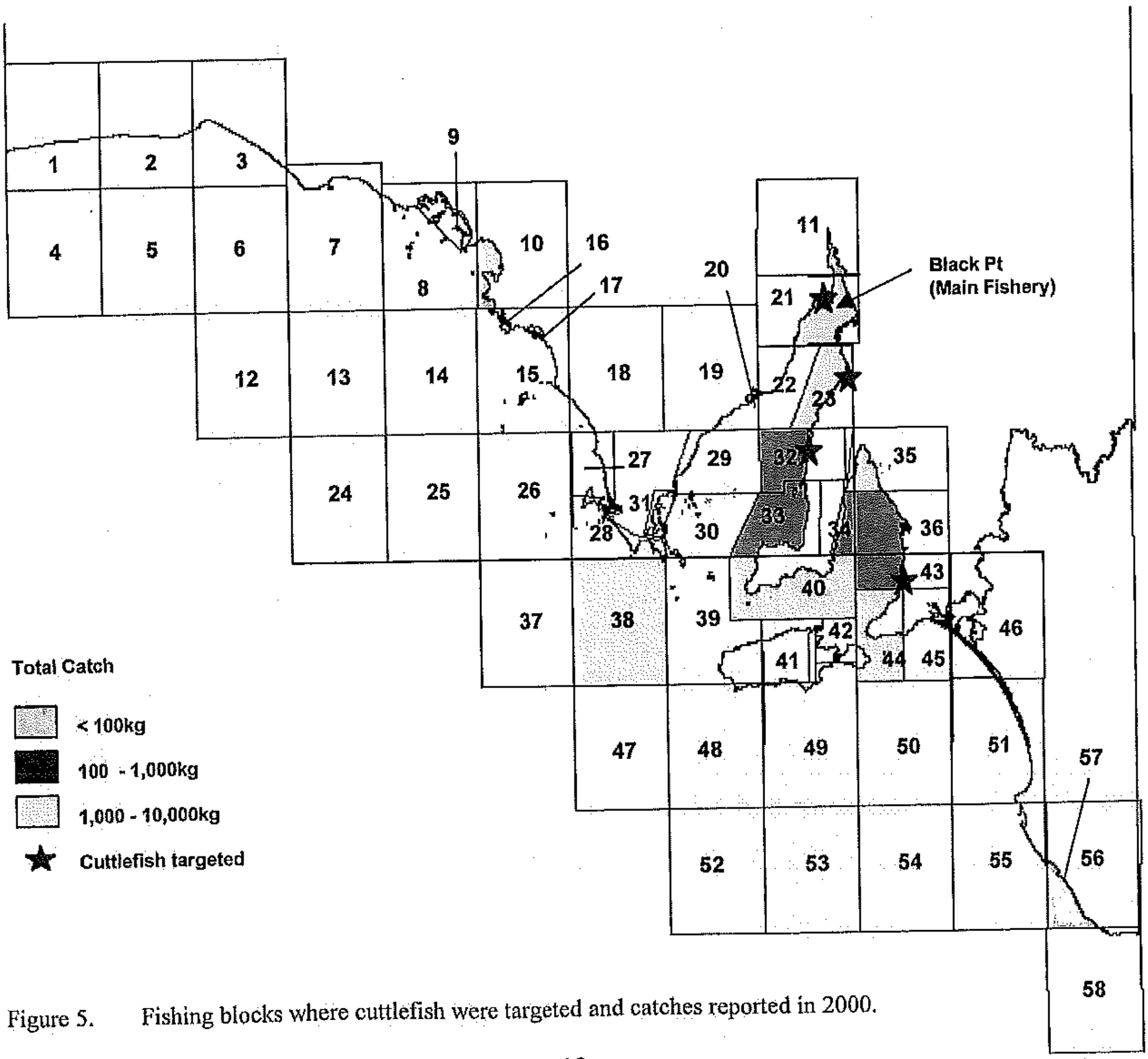


Figure 5. Fishing blocks where cuttlefish were targeted and catches reported in 2000.

Distribution of catch between licence holders

There was a substantial decline in the number of licence holders targeting cuttlefish in 1999 and again in 2000 (Table 4). Fewer than 5 of the 32 licence holders who reported catches in 2000, actively targeted the species, which represents over an 80% reduction in the number of fishers targeting cuttlefish since 1997.

All licence holders in 1999 and 2000 reported individual catches of less than 5t (Table 5). However, in previous years a small proportion of the total number of licence holders in the State took the bulk of the catch. In 1997, seven fishers reported catches of over 15t, and their combined catch was 150t accounting for 57% of the total catch of the State. This compares to the entire catch of the State in 1998 of 149t. Therefore, limiting the number of licence holders in the fishery alone, would be unlikely to reduce the overall catch.

Table 5. Distribution of total catches of cuttlefish in South Australia between licence holders for the last five years. (2000 data to June only).

Catch Range		1996	1997	1998	1999	2000
< 5t	No. licence holders	42	46	45	39	32
	Combined catch	19t	28t	24t	16t	14t
	% of total catch	23%	16%	16%	100%	100%
5 – 15t	No. licence holders	6	10	13		
	Combined catch	63t	71t	125t		
	% of total catch	77%	27%	84%		
> 15t	No. licence holders		7	< 5*		
	Combined catch		150t			
	% of total catch		57%			

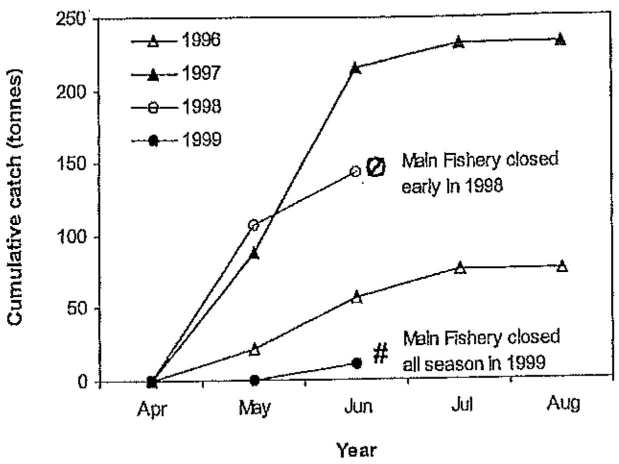
* NB: In 1998, less than 5 licence holders reported catches greater than 15t. These catches were included in the lower catch category for confidentiality reasons.

Seasonality of catch and effort

The cuttlefish fishery of South Australia is very seasonal, reflecting its dependence on the spawning aggregation in the Black Point to Point Lowly area and increased numbers of cuttlefish in other coastal areas during the winter months. Most catch is taken in the first two months (May and June) of the spawning season (Fig. 6a).

The highest monthly catch rates are also reported in May and June (Fig. 6b), corresponding to the time when cuttlefish are in their highest densities within the spawning aggregation. The average catch rate achieved in June of 1999 was well below those for the same month in previous years. This possibly reflects the naturally occurring lower densities of cuttlefish found outside the main spawning aggregation area, rather than a decline in abundance due to fishing. However, the lower catch rates recorded in 1998 as compared to 1997 and 1996 may be indicative of a decline in abundance of animals in the aggregation area. Note that, the data for 2000 could not be included in the analysis for confidentiality reasons, as fewer than 5 fishers targeted cuttlefish in that year.

a)



b)

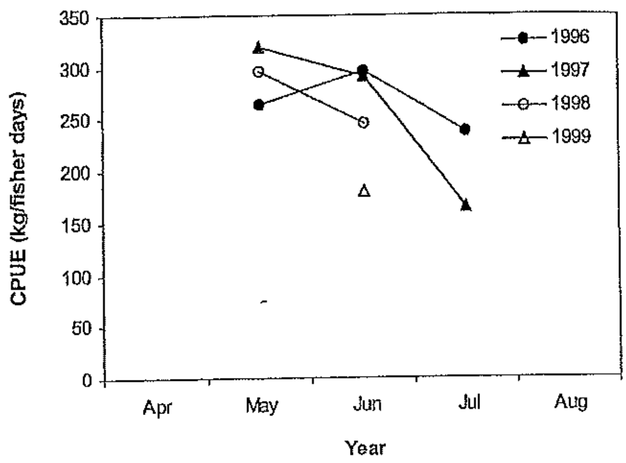


Figure 6. Monthly cumulative targeted catch *(a)* and monthly CPUE *(b)* of cuttlefish from Block 21 (1996 – 1999). Data for 2000 could not be included for confidentiality reasons, as fewer than 5 fishers were involved.

3.3. Abundance and biomass estimation

The annual abundance and biomass of *Sepia apama* in the aggregation area monitored over the last three years (1998 - 2000), using underwater visual counts. These data were used to generate simple abundance and biomass models for the spawning aggregation and to assess for any possible changes in stock size that may relate to fishing.

1998 Survey design

Before the 1998 fishing season, an area of coastline near the Port Bonython jetty (from Stony Point to the tip of Point Lowly) was closed to fishing to protect some spawning biomass in the absence of other management controls. Several sites within both the closed area and that remaining open to fishing were monitored throughout the spawning season (Fig. 7).

Habitat surveys were completed prior to the start of the spawning season to quantify the area of subtidal rocky reef habitat available in the closed and fished areas. Two main reef habitat types were identified - solid rock/reef habitat dominated by urchins close to the shoreline (referred to as the "urchin habitat"), and patch reef habitat dominated by tall algal stands and razorfish that was further from the shore (referred to as the "algae habitat").

1999 and 2000 Survey design

In both 1999 and 2000, the area west of Point Lowly to Whyalla was closed to fishing for the entire spawning season.

The results of the 1998 survey indicated cuttlefish were not evenly distributed within the aggregation area. Higher densities were recorded at Site 1 in the fished area (Black Point) and Site 1 in the closed area (Stony Point) and there were consistently more cuttlefish found in the "urchin habitat", than the "algae habitat" at all sites and times.

Therefore, in 1999 and 2000 the temporal survey was reduced to monitor only the "urchin habitat" at four sites, including Black Point and Stony Point. Only one complete spatial survey of all sites was completed each year, to coincide with the maximum level of biomass in the aggregation area.

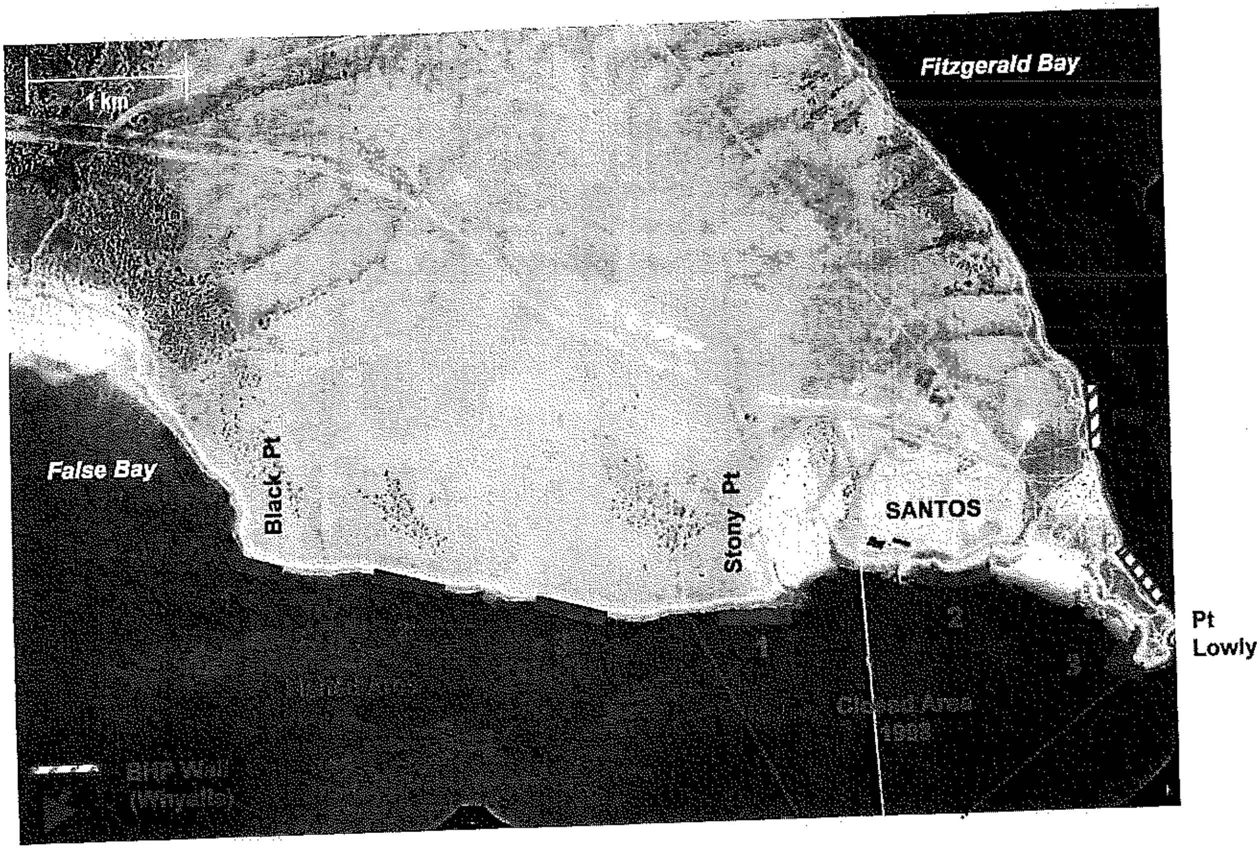


Figure 7. Location of sampling sites in the Black Point to Point Lowly area.

Survey methods

Four 2x50m transects were completed in each habitat type at each site and time monitored, to provide an estimate of average density per 100 m^2. An estimate of the average weight of cuttlefish per 100 m^2 was also calculated by converting the length estimate recorded for each cuttlefish (dorsal mantle length (DML)) to weight using the appropriate length-weight relationship. Validation of length estimates and sex determination was achieved by the removal of animals following estimation, for verification of lengths and sexes in the laboratory.

Abundance estimates

Abundance estimates were calculated for each site by multiplying the average density of cuttlefish per site by the appropriate estimate of reef area. Total abundances in the fished area and the closed area were estimated by combining the abundance estimates for all fished and closed area sites, respectively.

Biomass estimates

A biomass estimate for each site was calculated by multiplying the average weight of cuttlefish per unit area by the corresponding reef area estimate. Total biomass in the fished and closed areas were estimated by combining the abundance estimates for all fished and closed area sites, respectively. The cumulative commercial catch was added to the estimate of biomass for the fished area to provide an estimate of what the total biomass in the fished area might have been had fishing not occurred. By combining this with the estimate of total biomass in the closed area, an estimate of total biomass in the aggregation area was obtained.

3.4. Results of the 1998 – 2000 stock assessments

A summary of the findings of the three stock assessments for *Sepia apama* in the spawning aggregation area is provided below. In 1998, about 56% of the aggregation area was left open to commercial fishing for 32 days at the start of the spawning season, whereas in 1999 and 2000 the whole aggregation area was closed to fishing for the duration of the spawning season. Therefore, the results from the last two years are compared to those from 1998, where possible, to identify differences that may relate to fishing.

Reef area

The area of reef closed to fishing at the commencement of the 1998 fishing season was estimated to be 3.4 hectares, which represented 44% of the total reef available. That remaining open to fishing was estimated at 4.3 hectares which represented 56% of the total reef area.

Abundance

The abundance estimates for the two main sites in 1998, i.e., Black Point in the area left open to fishing and Stony Point in the area originally closed to fishing, are shown in Fig. 8a. At Black Point there was an initial rapid increase in numbers followed by a gradual decline throughout the remainder of the season. At Stony Point there was a more gradual increase in numbers and the decline in numbers did not start until later in the season.

In 1999, when neither site was fished, a similar temporal pattern was observed at both sites (Fig. 8b). At Black Point the abundance increased even faster during the first two weeks of May and reached a substantially higher abundance than in 1998, followed by a dramatic decline in late May and a more gradual decline from then on. At Stony Point numbers also increased rapidly during May, reached a higher abundance than in 1998, and gradually declined through the remainder of the season.

In 2000, again when neither site was fished, quite different temporal trends were observed for the two main sites (Fig. 8c). At Black Point there was a more gradual increase in numbers during May to a lower abundance than in 1999. Then there was a rapid decline in numbers during June followed by a second increase during July. At Stony Point numbers increased very rapidly during the last two weeks of May to a higher abundance than in 1999. The abundance remained high throughout June and slowly declined through July and August, such that there were still over 10,000 animals remaining in late August.

The estimate of total abundance increased from 117,000 in 1998 to 216,000 in 1999 (Table 6). A similar estimate was obtained in 2000, i.e., 215,500. Most of the increase in abundance was in the area fished in 1998 but closed to fishing in 1999 and 2000. Although this increase appears dramatic, there is no way of knowing what the total level of abundance in the area might have been in 1998 had fishing not occurred. We also do not know how these abundances compare with the virgin unfished abundance levels that occurred in the aggregation area prior to fishing. Given these uncertainties, we cannot conclude whether the levels of fishing reported in 1997 and 1998 were sustainable.

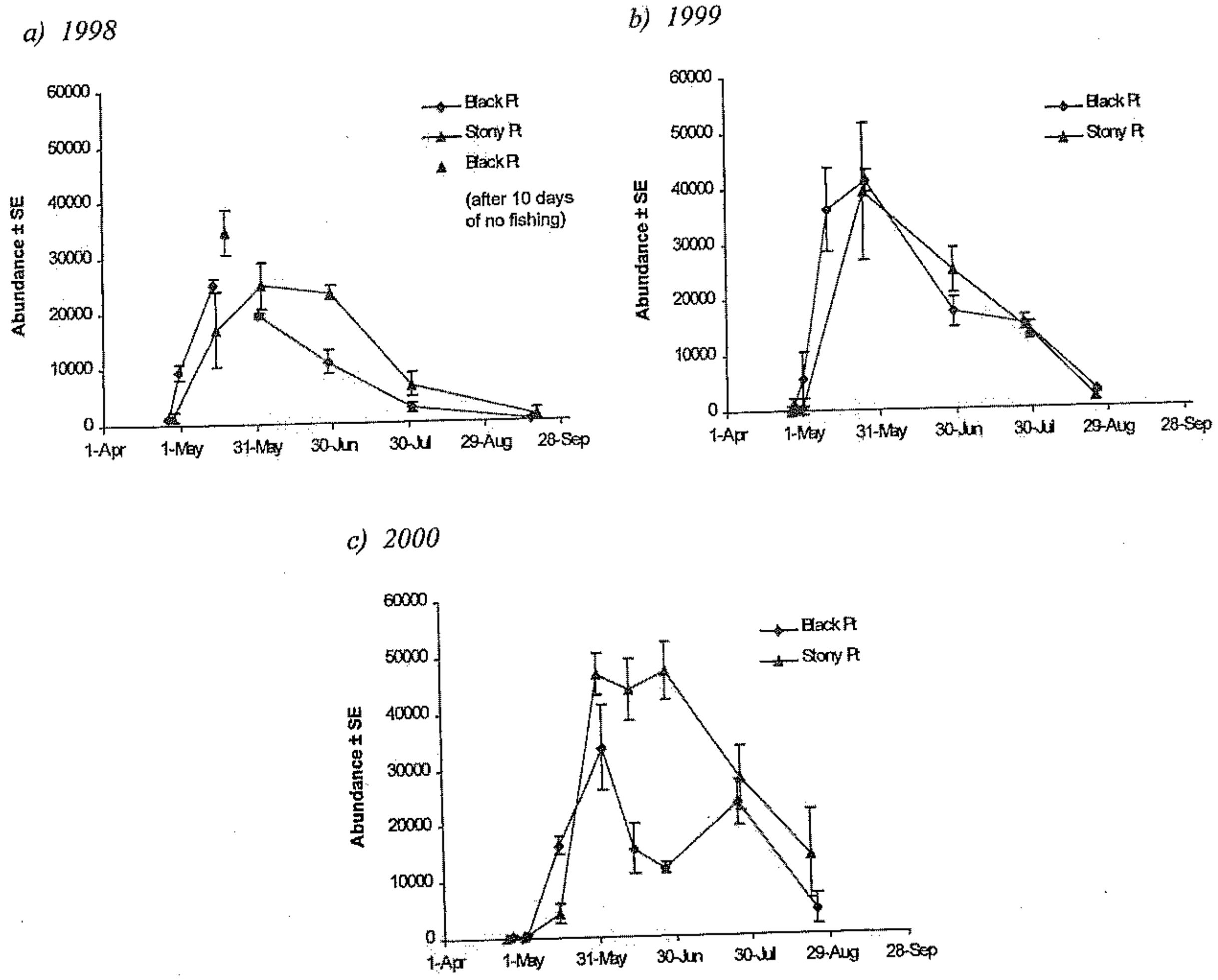


Figure 8. Total estimates of abundance for the two main sites at various times during the last three spawning seasons. NB: In the 1999 stock assessment report Fig. 8b was incorrect.

Table 6. Comparison of estimates of abundance for the last three spawning seasons (1998 - 2000).

Area	1998	1999	2000
TOTAL CLOSED AREA % estimated TOTAL ABUNDANCE	49,399 42%	53,797 25%	66,795 31%
TOTAL FISHED AREA % estimated TOTAL ABUNDANCE	67,700 58%	162,284 75%	148,667 69%
TOTAL Whole aggregation area	117,099	216,081	215,462

Biomass

The estimated total biomass was 218 t in 1998, 207 t in 1999 and 224 t in 2000 (Table 7 and Fig. 9). Although no monitoring was under way in 1997, the total commercial catch in the area in that year was 235 t. These estimates suggest the biomass has changed little over the last three years, following the intense fishing effort exerted in the area in 1997. However, since monitoring of the spawning aggregation did not commence until 1998, it is not known if the level of biomass surveyed in 1998 to 2000 had already been substantially reduced prior to the first year of monitoring. Anecdotal information from local divers who have been diving in the area for around 10 years maintain that levels of biomass have decreased since 1997.

Table 7. Comparison of estimates of biomass (in tonnes) for the last three spawning seasons (1998 - 2000) and the percentage breakdown of biomass for the closed area, fished area and catch.

Area	1998	1999	2000
TOTAL CLOSED AREA % of estimated TOTAL BIOMASS	49 22%	50 24%	68 30%
TOTAL FISHED AREA % of estimated TOTAL BIOMASS	60 28%	152 74%	154 69%
TOTAL Whole aggregation area	109	203	222
CUMULATIVE CATCH (Block 21) Biomass removed from FISHED AREA	109 50%	4* 2%	2* 1%
GRAND TOTAL Whole aggregation area	218	207	224

\# Amount removed as catch from Block 21 in 1999 and 2000 – potentially from Fitzgerald Bay and the BHP Wall at Whyalla.

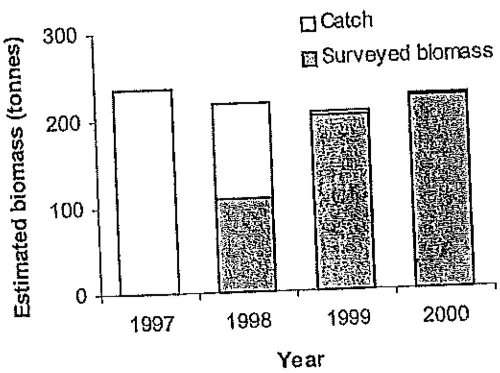


Figure 9. Annual estimated total biomass in the aggregation area.

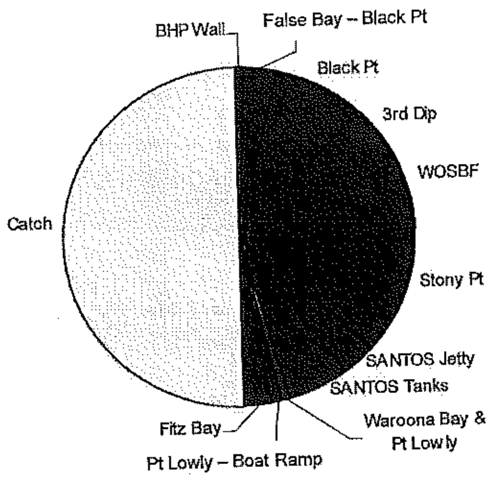
The spatial distribution of biomass within the aggregation area has changed over the last three years (Fig. 10). In 1998, the catch accounted for approximately 50% of the total estimated biomass, despite that the main fishery was closed early. The catch was clearly much lower in 1999 and 2000, due to the total closure of the main fishery.

The estimated biomass in the closed area (indicated in green, Fig. 10) changed little between seasons, accounting for only 22-30% of the total estimated. However, there was a shift in the proportion of biomass found at each individual site, as biomass increased at Stony Point but decreased at the other sites in both 1999 and 2000 (Fig. 10b).

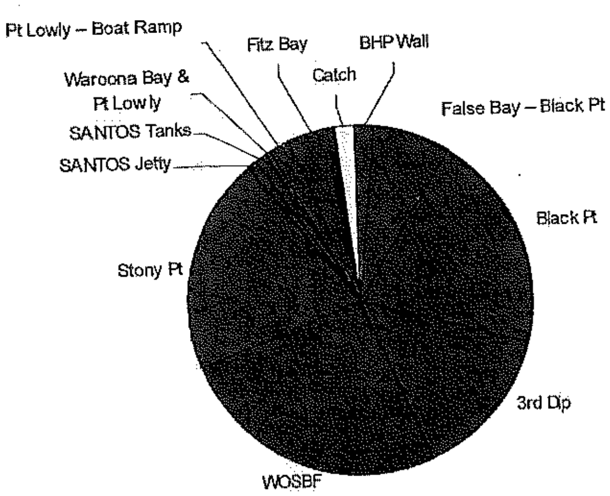
The estimated biomass in the fished area (indicated in red, Fig. 10) increased by 150% in 1999 and 2000 when the sites were not fished, from 60t in 1998 to 152t in 1999 and 154t in 2000 (Table 7). This increase in biomass was consistent across all fished sites in 1999 (Fig. 10b). However, in 2000, the site just west of the SANTOS boundary fence (adjacent to the original closed area) recorded very high densities (even higher than Black Point) and accounted for the greatest percentage of the total biomass. Alternatively, the site between False Bay and Black Point, and even Black Point which previously always had the highest level of biomass, showed a noticeable decrease in biomass in 2000. Similarly, both Fitzgerald Bay and the site between Point Lowly and the boat ramp, showed a decreased biomass in 2000. Both these sites remained open to fishing in 2000.

Figure 10. Breakdown of the estimated total biomass according to individual sites monitored and amount removed as catch at the end of May in each year (1998 – 2000). Original closed area sites are indicated in green, fished sites in red and the catch in yellow. Values provided in Appendix I.

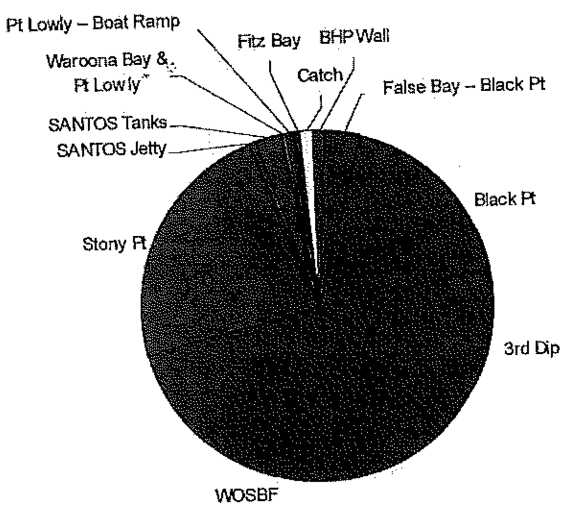
a) 1998 – 220 tonnes



b) 1999 – 211 tonnes



a) 2000 – 218 tonnes



Size and age structure

A comparison of the size structure of male *S. apama* recorded on underwater transects within the Black Point site for the last three years with those of samples taken from various locations around Spencer Gulf during the subsequent summer months (Fig. 11, 12 and 13), provide an interesting insight into the possible life history of this species. A wide range of size classes were evident in all years both at Black Point during the spawning season and in the summer samples, which is difficult to reconcile with the commonly held view that *S. apama* is an annually spawning semelparous species.

Of particular interest is the small size class of animals present in the February (Fig. 11h and 12g) and April (Fig. 11j and 12h) samples, which appear to be new recruits that were spawned the previous winter coming through. These would clearly not reach even the smallest adult size classes by the start of the spawning season that year in late April/early May.

Similarly, the presence of small adult-sized cuttlefish in November (Fig. 11g.) does not support the notion of all animals being of similar age and dieing at the same time following spawning in September. The existence of these animals is completely contrary to the current understanding of the life history and suggests that the population may consist of several year classes. Evidence to support the link between the wider Spencer Gulf samples and those aggregating at Black Point does exist (if somewhat tenuously) in that one cuttlefish tagged from Plank Shoal in April 2000 was recaptured at Black Point in July 2000.

Another point of relevance to the fishery is apparent change in the size structure of the spawning population over the last three years (Table 8). There was a decline in the percentage of both large males (> 300 mm DML) and small animals (both male and female; ≤ 150 mm DML) in the spawning population at Black Point from 1998 and 1999, to 2000. This trend was also evident at the Stony Point and BHP Wall sites. This finding is consistent with the results from the analysis of the length frequency data, which suggested that the population consists of several year classes. A change in the size structure may alter the underlying mating system of the spawning aggregation, as different sized males were found to have very different reproductive behaviours. In addition, the loss of large males from the aggregation alters the value of the area as a dive location, as the large displaying males are of most appeal to underwater observers.

Table 8. Percentage of animals observed on transects that were small (≤ 150 mm DML) and percentage of males observed on transects that were large (> 300 mm DML) (1998 – 2000).

Year	Date	% Small animals (≤ 150 mm DML)			% Large males (> 300 mm DML)		
		Black Pt	Stony Pt	BHP Wall	Black Pt	Stony Pt	BHP Wall
1998	14/5/1998	9.9	12.4	6.1	5.6	6.5	-
	1/6/1998	33.3	16.9	10.9	7.2	4.5	4.5
	28/6/1998	18.8	19.7	9.2	4.1	7.6	3.8
1999	11/5/1999	0.9	-	-	9.4	-	-
	26/5/1999	10.9	2.0	7.1	4.7	0.6	9.3
	29/6/1999	23.9	8.5	18.1	1.1	1.0	2.3
	28/7/1999	10.4	1.4	14.2	1.3	0.0	1.1
2000	16/5/2000	3.7	0.0	5.4	0.0	5.3	0.0
	1/6/2000	0.0	0.0	0.5	3.3	0.5	0.6
	14/6/2000	1.9	1.8	1.1	1.2	0.0	0.4
	26/6/2000	1.2	0.4	3.6	0.0	1.0	0.9
	25/7/2000	6.0	1.4	11.0	0.7	1.6	1.9
	22/8/2000	-	2.7	-	-	0.0	0.0

NB: Accuracy of length estimations were verified in the laboratory by the removal of a sample of animals following length estimation underwater (Appendix II).

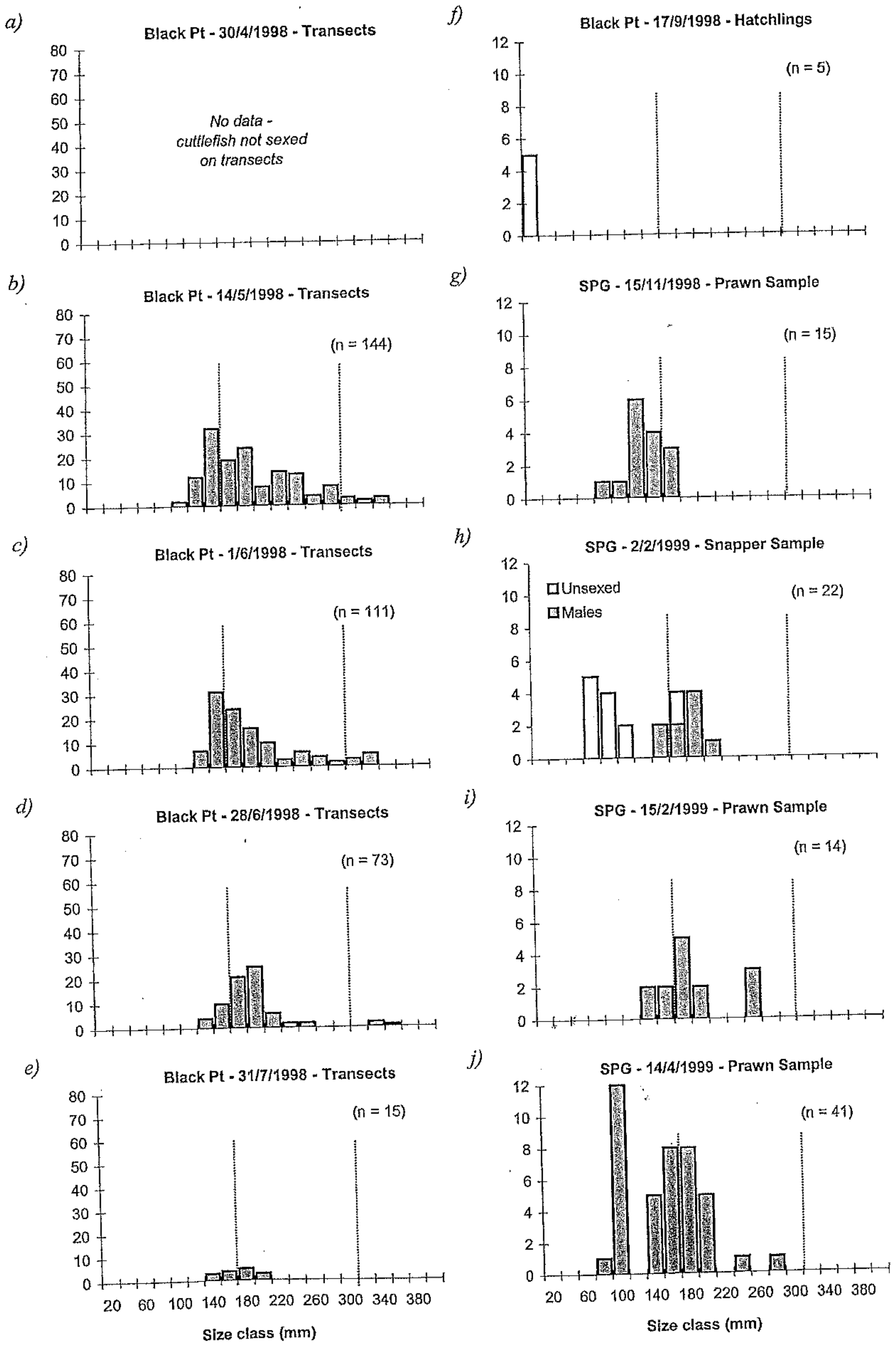


Figure 11. Length frequency histograms of male *Sepia apama* observed on transects at Black Point *(a)* to *(e)*; collected from around Spencer Gulf by prawn trawlers *(g)*, *(i)* and *(j)* and juvenile snapper sampling *(h)*; and hatchlings collected from Black Point *(f)* (1998/1999).
NB: Animals left of 1st dashed line are <160mm DML and right of 2nd dashed line are >300mm DML.

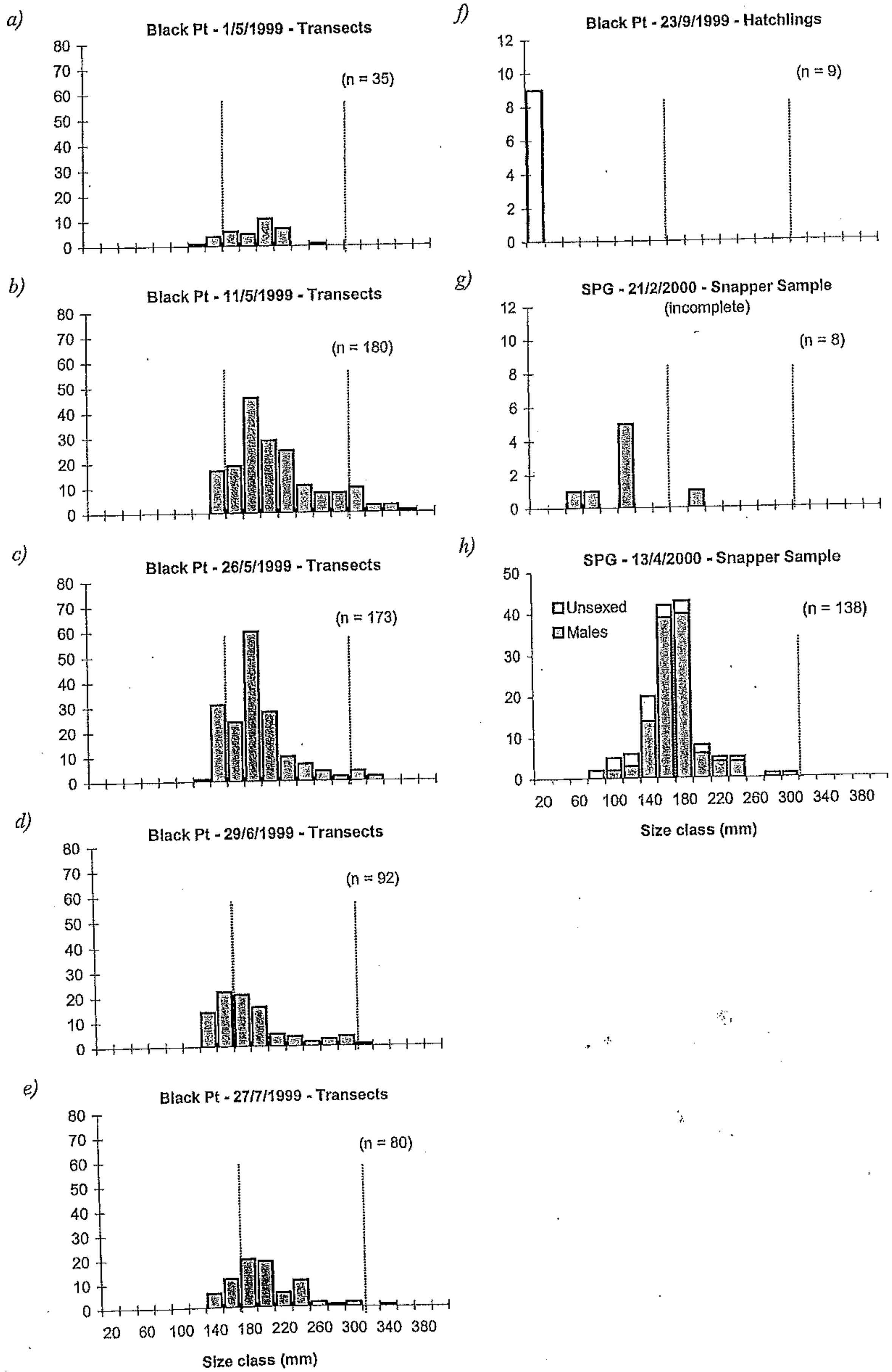


Figure 12. Length frequency histograms of male *Sepia apama* observed on transects at Black Point *(a)* to *(e)*; collected from around Spencer Gulf by juvenile snapper sampling using an otter trawl *(g)* and *(h)*; and hatchlings collected from Black Point *(f)* (1999/2000).
NB: Animals left of 1st dashed line are <160mm DML and right of 2nd dashed line are >300mm DMI

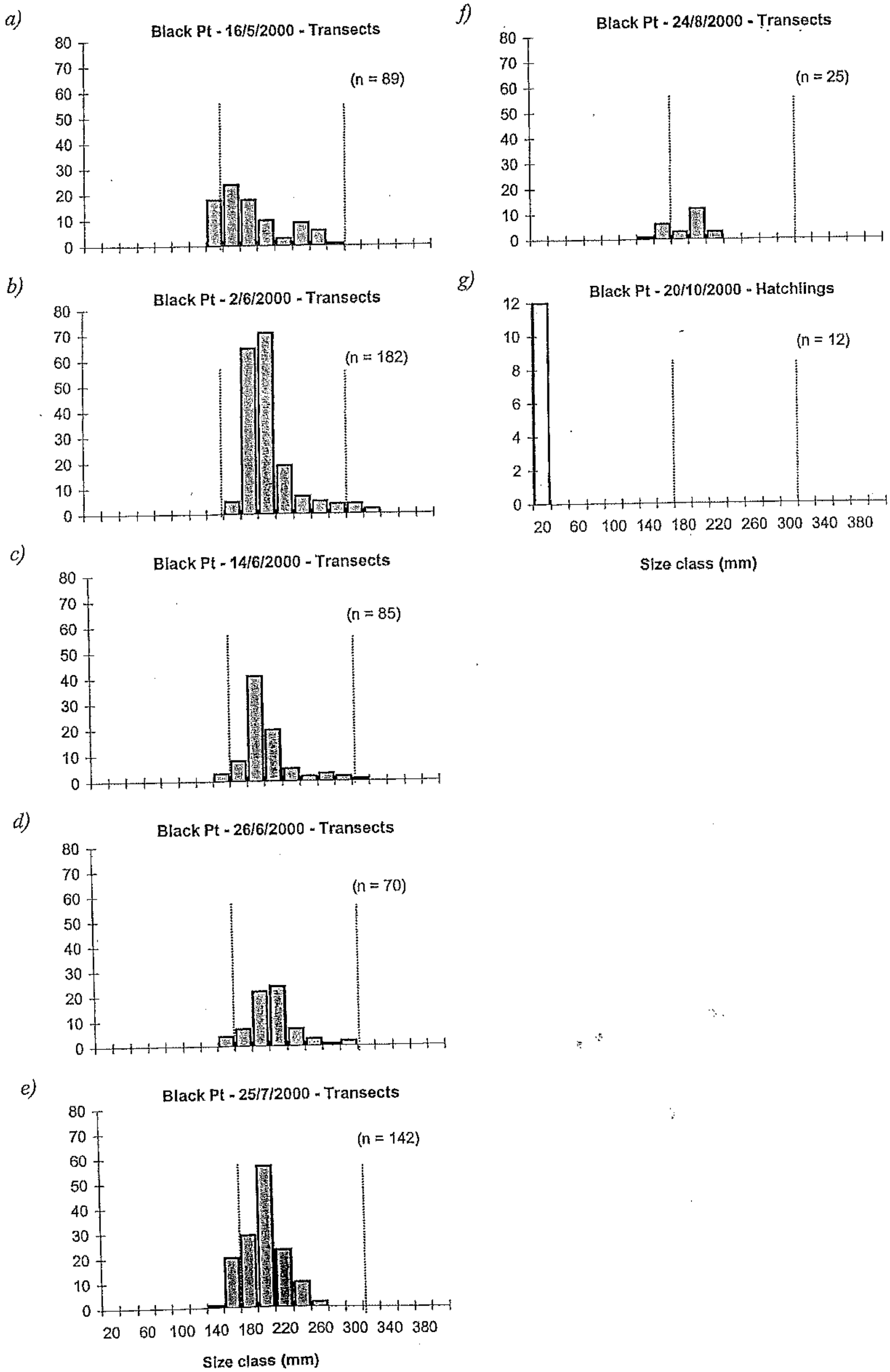


Figure 13. Length frequency histograms of male *Sepia apama* observed on transects at Black Point *(a)* to *(f)*; and hatchlings collected from Black Point *(h)* (2000).
NB: Animals left of 1st dashed line are <160mm DML and right of 2nd dashed line are >300mm DMI

Sex ratios

One peculiar feature of the spawning aggregation is the consistent bias in the sex ratios towards males (Table 9). On average there are 3.4-5.4 males to each female. This has significant implications for the sustainability of the stock as only about 25% of the biomass each year contributes to egg deposition. In 2000, this would equate to approximately 56 t of females.

Table 9. Sex ratios (M:F) recorded at the two main sites via underwater transects over the last 3 spawning seasons (1998 – 2000).

Year	Date	Black Pt	Stony Pt
1998	14/5/1998	3.8 : 1	6.4 : 1
	1/6/1998	4.2 : 1	6.0 : 1
	28/6/1998	8.1 : 1	3.2 : 1
	Average	**5.4 : 1**	**5.2 : 1**
1999	11/5/1999	3.0 : 1	-
	26/5/1999	3.9 : 1	5.6 : 1
	29/6/1999	3.6 : 1	3.8 : 1
	28/7/1999	3.0 : 1	2.1 : 1
	Average	**3.4 : 1**	**3.8 : 1**
2000	16/5/2000	4.7 : 1	-
	1/6/2000	3.1 : 1	5.6 : 1
	14/6/2000	4.0 : 1	3.6 : 1
	26/6/2000	4.9 : 1	4.7 : 1
	25/7/2000	5.8 : 1	7.5 : 1
	22/8/2000	-	2.8 : 1
	Average	**4.5 : 1**	**4.8 : 1**

Movement Studies

The method currently used to estimate total abundance and biomass (presented in Tables 6 and 7) relies on the assumption that most animals arrive in the aggregation area before any start to leave, resulting in a peak level of abundance and biomass at some point that can be surveyed and estimated. If there was a constant turnover of animals in the area the method would underestimate the true abundance and biomass of cuttlefish coming into the area over the course of the spawning season. In 1999, concerns were raised as to the validity of this assumption.

Our original assumption was that most cuttlefish upon arrival into the spawning grounds found a mate, established a territory and remained in approximately the same spot for the duration of the spawning season. This was based on study a of the spawning behaviour of *S. apama* in the waters adjacent to Edithburgh in southern Gulf St. Vincent (Rowlings 1994). Rowlings found spawning males to be extremely territorial with a high site fidelity. Tagged cuttlefish were repeatedly observed occupying the same location on successive occasions through the spawning season. He likened this to the den ecology commonly observed for octopus. In addition, he observed the same suite of males present for the duration of the spawning season.

In May 1999, a substantial period of focal animal behavioural sampling was completed on the spawning aggregation. Individual cuttlefish were followed for around an hour each and their behaviour recorded on video tape. The sampling revealed a very different pattern of behaviour to that expected. Competition for females was fierce and there was a regular mixing and changing of pairs. The whole mating system was very dynamic. Males moved large distances (100's of meters) in search of mates and females moved considerably (10's of metres) during the hour, in search of egg laying sites.

To better understand movement patterns of cuttlefish within the spawning grounds during the season and determine the length of time spent in the area by individual cuttlefish, a tagging study was undertaken during the 2000 spawning season. Animals were tagged at the BHP Pellet Plant Wall site at Whyalla due to the high density of animals there, contained within a small area (easier to search entire area for resighting of cuttlefish). A total of 233 cuttlefish were tagged in the first two weeks of May (182 males and 51 females).

There were two types of movement by cuttlefish from the BHP Wall area. A consistent number of cuttlefish (mean = 12.7; SE = 2.4; 5% of total tagged) were resighted within the wall area on a number of occasions up to 6 weeks after tagging. Thus representing a small proportion of "stayers" that moved little after reaching the wall area. The maximum time any tagged animal was recorded to spend in the area was one small male captured adjacent to the BHP Wall area 9 weeks after tagging.

The remainder apparently moved on from the BHP Wall area, possibly to the main aggregation area. Five moved long distances. Three were small males which moved to Black Point 7 days after tagging, whilst a large male was also sighted at Black Point after 4 weeks. A tagged female was seen at Stony Point after 6 weeks.

Although the number of sightings was low, the tagging study indicates that individual cuttlefish may spend up to 6 weeks within the aggregation area, possibly even longer. Females and large males were also included within those animals sighted 6 weeks after tagging. Therefore, it appears individual cuttlefish are resident in the aggregation area for a large proportion of the spawning season. However, it was also evident that many cuttlefish move considerable distances within in the aggregation area, which should be taken into account when designing closed areas within the overall aggregation area.

3.5. Reliability of assessments

The formulae used to estimate total abundance and biomass relies on direct multiplication of the average density obtained from count data by the estimate of the area of reef. Therefore, any error in the estimate of reef area would translate directly into the biomass or abundance estimates. For example, Fig. 14b shows the results of the annual biomass calculations if the estimate of reef area was reduced by 20%, i.e., corrected for an overestimation of 20% in our current estimates of reef area. It is unlikely that the error in our current estimates of reef area would exceed 20%.

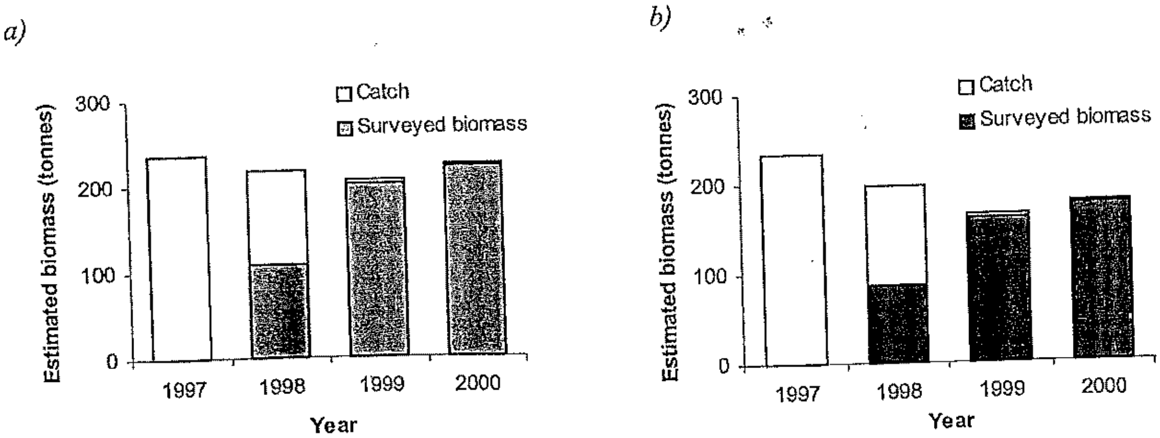


Figure 14. Annual estimated total biomass in the aggregation area *(a)*, and with estimates adjusted for a 20% overestimation in either reef area or average density *(b)*.

The estimated biomass for 1999 and 2000 was reduced by the full 20%, but that for 1998 was not reduced as much, due to the substantial catch in that year that was not subject to the 20% error. A 20% overestimation of the reef area would result in a more significant decline in the biomass to remain undetected.

3.6. Future assessment needs

Continued estimation of the abundance and biomass of cuttlefish at the spawning grounds each year is essential to provide pre-fishing estimates of the potential level of stock available to the fishery. Furthermore, an understanding of the relationship between the spawning biomass of one year and the recruitment to the fishery in subsequent years would help determine appropriate biological reference, against which to compare the biological and fishery indicators for cuttlefish. The collection of catch and effort data on a finer temporal scale (ideally daily) is recommended to better monitor the exploitation rate during the relatively short fishing season. Further tagging and genetic work needs to be carried out to assess the relationship between cuttlefish spawning at Black Point and those found throughout the Spencer Gulf at other times of the year. Research in 2001 will also focus on determining the number of year classes in the population, and which age classes are represented in the spawning aggregation.

4. MANAGEMENT IMPLICATIONS

4.1. Summary of findings

A number of findings from the 2000 stock assessment with respect to the biological and fishery indicators are worthy of consideration:

Fishery indicators - the temporal and spatial variation in annual total catch, targeted fishing effort and catch rate.

1. The time and area closures in place for the 1999 and 2000 spawning seasons effectively reduced the total catch and effort in the commercial cuttlefish fishery. Total commercial catch declined from 145 t in 1998 (when the fishery was open for half the season) to 16 t in 1999 and 14 t in 2000.

2. The decrease in catch reflected a decrease in effort from 535 fisher days in 1998 to 98 fisher days in 1999 and only 63 fisher days in 2000. Fewer than 5 fishers targeted cuttlefish in 2000, over an 80% reduction in the number of fishers targeting cuttlefish from 1997, when there were no restrictions on the taking of cuttlefish.

3. Even with the closure in 2000, >80% of the targeted catch of cuttlefish was still taken from Block 21 (the fishing block encompassing the aggregation area), possibly from areas adjacent to the closed area.

4. The low CPUE values recorded in 1999 and 2000 possibly reflect the low densities of cuttlefish present outside of the aggregation area.

Biological indicators – estimates of annual total abundance and biomass of cuttlefish at the main spawning grounds, derived by fisher-independent surveys.

5. The timing of the spawning season in 2000 was slightly later than in previous years, with cuttlefish numbers not increasing until mid-May and higher numbers of animals remaining in the aggregation area at the end of August. Such inter-annual variation in timing of the spawning

season highlights the need to allow some time either side of the "normal" spawning period if a total closure of the spawning aggregation to fishing was considered. A proposed period would be from mid April until the end of September.

6. The annual estimates of total biomass from 1998 to 2000 were 218 t, 207 t and 224 t respectively. These are substantially lower than the total catch of 1997 (235 t), and thus clearly lower again than the total abundance for 1997. Because population monitoring did not commence until after substantial catches were removed in 1997 and 1998, the residual influence of that intense fishing is now indeterminable.

7. There were some small scale changes in the spatial distribution of biomass within the aggregation area which may be indicative of some effects of the intense fishing. The most significant was the dramatic increase (150%) in abundance and biomass in all previously fished sites following the closure to fishing in 1999. There was a similar decline in abundance at two sites outside the total closure area that were still fished in 1999 and 2000.

8. In 2000, there was a slight decrease in abundance and biomass at Black Point and False Bay and a big increase in the area just west of the SANTOS boundary fence (adjacent to the original closed area) and a slight increase in the Stony Point area. These changes may reflect an effect of the smaller closed area implemented in the 1998 spawning season.

9. The sex ratio of the spawning population is very biased towards males. On average there are 3.4-5.4 males to each female. This has significant implications for the sustainability of the stock, given that in a year such as 2000, only 25% of the animals present (equates to 56 t) contribute to the egg deposition.

10. An analysis of the size structure of males present in the spawning aggregation and those caught in subsequent summer months from the wider Spencer Gulf area, suggest that there may be several year classes of animals in the population. These results are incompatible with the accepted view of *Sepia apama* being an annual species.

11. Furthermore, the percentage of large males (> 300 mm DML) and small animals (< 160 mm DML) has declined from 1998 and 1999, to 2000. This finding is consistent with the results from the analysis of the length frequency data which, which suggested that the population may consist of several year classes.

12. Our current method of estimating the abundance and biomass of animals in the aggregation area relies on the assumption that individual cuttlefish spend the majority of the spawning season in the area. In 1999, concerns were raised over the validity of this assumption. Tagging studies completed in 2000, indicated that individual cuttlefish may spend up to 6 weeks within the aggregation area, possibly even longer, which constitutes a large proportion of the spawning season. This finding strengthens our confidence in the reliability of our estimates of abundance and biomass.

13. Another finding of the tagging study, was that some tagged cuttlefish moved considerable distances (approximately 15km) within the aggregation area in a matter of days. The movement patterns of the cuttlefish appear to encompass the whole aggregation area. This has implications for determining the appropriate sizes of closed area, if an open area/closed area strategy, such as that implemented in 1998, was to be considered in the future.

14. At present the estimates of abundance and biomass are useful relative measures for annual comparisons. Their accuracy in terms of estimating the true biomass depend on our estimates of reef area. It is unlikely that the error in our current estimate of reef area would exceed 20%. At this level our estimates of biomass for 1999 and 2000 would be lower in relation to 1997 and 1998.

4.2. Market and economic considerations

Commercial fishery sector

The value of cuttlefish to commercial fishermen is quite low (average price of around $0.40 - $2.00 per kg). They, therefore, need to achieve high catch rates (greater than around 700 kg/day) to ensure sufficient economic benefit. The low price received for cuttlefish in Australia is a reflection of the low domestic demand for the product and relatively low export price received by processors. If the profit margin of processors was increased through better marketing, it might lead to higher returns for fishers.

It should be noted, however, that not all of the commercial catch of cuttlefish is sold for human consumption. Cuttlefish is considered excellent bait for commercial and recreational fishing for snapper, sharks and King George whiting. The level of dependence by fishers on cuttlefish for bait purposes is currently unknown, and requires further collection of data and analysis, but is considered to be quite high. Most of the 14 t of commercial catch taken in 2000 was used for bait.

Seafood processing and export sector

Sepia apama might fetch a higher export price if appropriate processing, packaging and markets were identified.

This species is one of the largest cuttlefish species in the world commonly ranging from 0.5-3 kg each whole weight and 0.2-1 kg each cleaned mantle weight. Larger cuttlefish species tend to fetch higher prices in all markets. Furthermore, the product is of very high quality when caught using hand lines and jigs compared to trawling, which is the method most commonly used in foreign cuttlefish fisheries. The catch can also be transported to Adelaide overnight for processing the following day, such that it could easily be air-freighted fresh as opposed to frozen. Fresh whole and processed cuttlefish fetch a much higher price in Asian markets than the frozen product.

Due consideration needs to be given to the price fluctuations common in the Asian markets for cephalopods. In 1998, one Adelaide processor recorded a loss of $0.80 per kg on a large shipment of cuttlefish due to a drop in price that resulted from a surplus in supply and the regional economic downturn.

Cuttlefish prices in Asian markets tend to be influenced by trends in squid supply (Court 1999). Prices in the Tokyo markets are generally higher in April and May prior to commencement of the main Japanese squid fishing season. They then drop during June and July as fresh squid flood the markets. An average price of ¥714 per kg (about AUS$10 per kg) for whole fresh cuttlefish was recorded at the Japanese Tsukiji Auction market (Tokyo) in May 1999 (Lin G. 1999, pers. comm.). Processed fresh cuttlefish fetched prices as high as ¥1,680 per kg (about AUS$24 per kg), depending on quality of processing and packaging.

Recreational diving and tourism sector

There are numerous attractive aspects of the aggregation to the recreational diving and tourism sector: the aggregation is unique in the world; the cuttlefish are large, abundant and their mating displays spectacular; the site is accessible to divers of all standards; and is relatively sheltered from prevailing weather.

Considerable financial benefit from the recreational dive interest is being gained by local dive and tourism operators (Table 10). Over 640 people visited the Whyalla region in 1999 to dive on the spawning aggregation (Bramley T. 1999, pers. comm.). The visitors completed approximately 3,000 dives and contributed an estimated $180,000 to the local Whyalla economy (Bramley T. 1999, pers. comm.), through dive-related expenses, accommodation, travel and living expenses. A further 1,000 dives with direct expenditure of about $30,000, were also completed by local residents and dive club members. In addition, 4 film crews visited Whyalla during the 2000 spawning season with a total expenditure of around $80,000.

Table 10. Estimates of the value of the cuttlefish spawning aggregation to the South Australian recreational diving and tourism sector. Estimates provided by Tony Bramley of Whyalla Diving Services.

Year		Number of Visitors	Number of Dives	Itemised Value	Total Value
1997	- Non-local visitors			$8,000	$18,000
	- Local			$10,000	
1998	- Non-local visitors	112		$12,000	$44,000
	- Local			$6,000	
	- Scientific (expenditure)	5*		$8,000*	
	- Film crews (expenditure)	3		$18,000	
1999	- Non-local visitors (directly as result of cuttlefish)	420	1,260	$55,000	$114,000
	- Local		900	$12,000	
	- Scientific (expenditure)	11*	133*	$11,000*	
	- Film crews (expenditure)	2	150	$36,000	
2000	- Non-local visitors (directly as result of cuttlefish)	670	3,500	$180,000	$310,000
	- Local	90	1,000	$30,000	
	- Scientific (expenditure)	11*	142*	$20,000*	
	- Film crews (expenditure)	10	220	$80,000	

*Estimates calculated from SARDI field logbooks and expense records.

NB: In the 1999 stock assessment report, 1997 and 1999 data were erroneously reversed.

The total expenditure related to the spawning aggregation by the recreational dive and tourism sector has risen by a factor of 17 times over the last 4 years (Table 10) from approximately $18,000 to $310,000. Further increases are expected next year with many bookings already confirmed, including return visits by film crews and international scientists. There is strong support and interest from the local Whyalla community for a marine reserve to be established for the area during the spawning season. The dive site is being promoted through an internet web site "Cuttlefish Capital of the World", which has recorded 262,000 hits since it's launch in June 1999, many from overseas. Further interest in the aggregation nationally has been generated through articles in national dive magazines and high profile television programs screened throughout 2000.

4.3. Environmental issues

In northern Spencer Gulf cuttlefish are preyed upon by dolphins, Port Jackson sharks, snapper and seabirds. In other places they are eaten by fur seals, sea lions and other marine mammals (Gales *et al.* 1993). How the aggregation at Black Point impacts on the diets of such animals through the winter is not known.

4.4. Management considerations

There was a considerable catch of 235 t of cuttlefish removed from northern Spencer Gulf in 1997 and early 1998. The consequences of this on population biomass cannot easily be determined since the only information available before the closure were commercial catch and effort data, whilst the best data available since then are estimates of abundance and biomass determined from the underwater visual surveys. The two datasets derived in different ways do not provide estimates of biomass that are directly comparable.

We have acknowledged that there are two aspects of uncertainty regarding the estimates of biomass from the visual surveys. Firstly, if we have over-estimated reef area by some proportion this will result in a similar proportional error to the estimates of abundance and biomass. Our simulation indicated that under such circumstances, our estimates of spawning biomass in 1999 and 2000 would be even lower relative to those of 1997 and 1998. The second concern about the visual surveys was our lack of understanding of the turn-over rate of animals in the aggregation throughout the spawning season, but yet the abundance estimates were based on the assumption of a considerable residence time. Fortunately, the tagging work done through 2000 demonstrated that the residence time was long, and thus supported the assumption. Considering both these issues together, i.e., the estimates of reef area and the issue of residence time, we are confident that if our estimates of biomass are in error, they overestimate the population biomass.

Consequently, the conservative interpretation of data available from 1997 to 2000 is that there has been a substantial decrease in the population biomass through this period. Such a decrease should be considered in the context of the view that we currently have no idea about what minimum biomass is necessary to ensure that the population does not enter a phase of recruitment overfishing. At this time it is timely to recall the uneven sex ratios of the population, and that of a standing stock of 200 t only 56 t are constituted by mature, reproductive females.

Another development of the biological work is the analysis of size frequency distributions that were presented in this report. These data have caused a complete revision of our understanding of the life-history of this species. To date, the accepted model was that *Sepia apama* is an annual species. However, the size frequency data are incompatible with this, suggesting that the population actually consists of several year classes. This is further supported by the observation that the population structure has changed through the years of 1998-2000. From a perspective of population dynamics a multi-year class fishery would respond differently to an intensive fishing regime than would a species consisting of a single year class. The population structure should now be considered as being more complex, and the management of the fishery considered in this light. This radical change to our understanding of life-history and its implications contrast directly with the view that was presented in the Management Considerations of the last report (Hall 1999). From a research perspective, in 2001 the biological research will focus on determining the number of year classes in the population, and which age classes are represented in the spawning aggregation.

Cuttlefish currently attract a low market price, which means that large catches are required for economic viability of the commercial fishery. However, there may be opportunities to increase the unit value of the catch through better marketing, and not all of the commercial catch is sold for human consumption. Cuttlefish is considered excellent bait for commercial and recreational fishing for snapper, sharks and King George whiting. The level of dependence by fishers on cuttlefish for bait purposes is currently unknown, and requires further collection of data and analysis. There are other stakeholders, however, who gain economic return from the aggregation not being fished. These include the recreational dive and tourism sectors, and the film and television industry, who are attracted to the unique nature of the aggregation.

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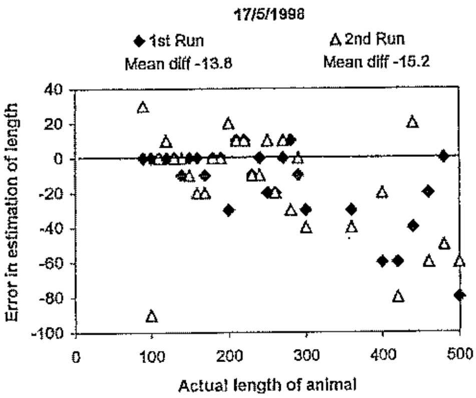
APPENDICES

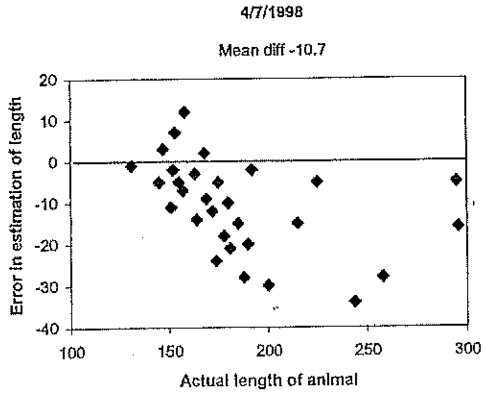
Appendix I: ***Detailed break down of abundance and biomass estimates spawning seasons and individual sites.***

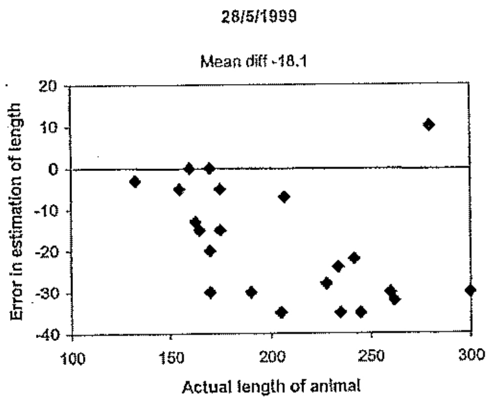
Area	1998 Abund (numbers)	1998 Biomass (tonnes)	1999 Abund (numbers)	1999 Biomass (tonnes)	2000 Abund (numbers)	2000 Biomass (tonnes)
CLOSED AREA						
Stony Pt	25,884	27	44,624	41	50,124	50
SANTOS Jetty (estimated)	7,042	7	1,386	1	4,897	5
SANTOS Tanks	12,495	12	2,264	2	7,999	9
Waroona Bay Reef (estimated)	1,389	1	236	0	834	1
Pt Lowly	715	1	1,286	1	463	1
BHP Wall	1,874	2	4,001	4*	2,478	2
TOTAL SURVEYED CLOSED AREA	**49,399**	**49**	**53,797**	**50**	**66,795**	**68**
Percent of TOTAL ESTIMATED BIOMASS		22%		24%		30%
FISHED AREA						
False Bay – Black Pt	7,797	7	16,368	15	6,309	7
Black Pt	20,819	18	47,916	42	36,955	39
3rd Dip	15,859	13	31,370	29	32,779	34
West of SANTOS Boundary Fence	13,738	14	51,692	53	69,174	71
Pt Lowly – Boat Ramp	2,609	2	4,108	4*	1,817	2#
Fitz Bay	6,878	5	10,830	9*	1,634	1#
TOTAL SURVEYED FISHED AREA	**67,700**	**60**	**162,284**	**152**	**148,667**	**154**
Percent of TOTAL ESTIMATED BIOMASS		28%		74%		69%
TOTAL SURVEYED Black Point to Point Lowly Area	**117,099**	**109**	**216,081**	**203**	**215,462**	**222**
CUMULATIVE CATCH (Block 21)		**109**		**+4**		**+2**
Percent of TOTAL ESTIMATED BIOMASS		50%		2%		1%
GRAND TOTAL Black Point to Point Lowly Area		**218**		**207**		**224**

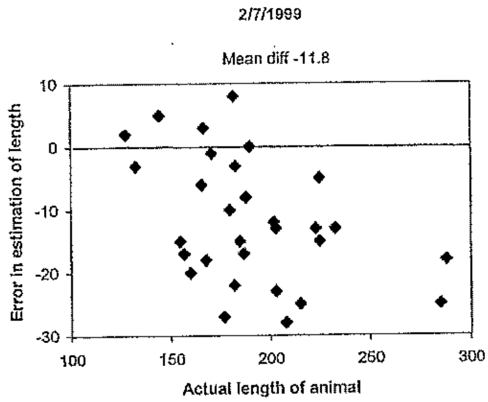
* Sites that were open to fishing in 1999.
\# Sites that were open to fishing in 2000.
+ Amount removed as catch from Block 21 in 1999 and 2000 – possibly from those sites remaining open to fishing.

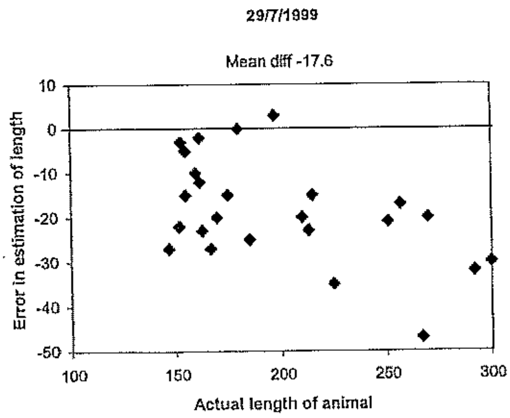
Appendix II: Residual plots of errors in length estimation at various times in the three spawning seasons (1998 - 2000).

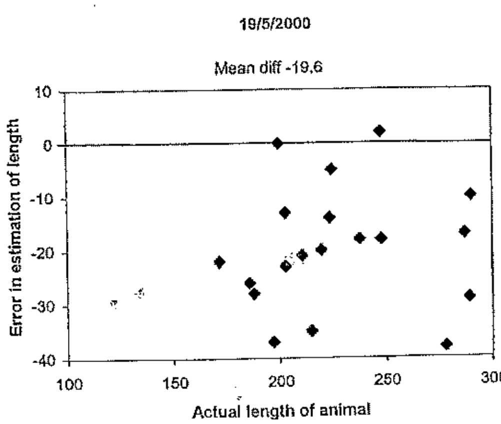


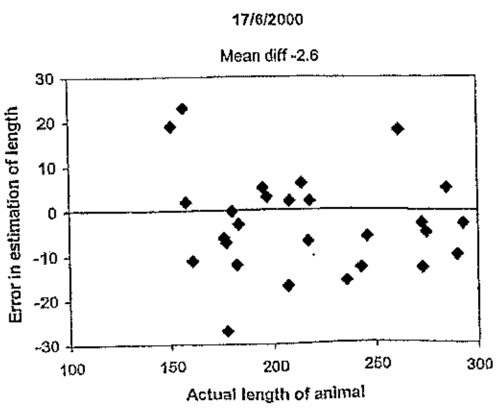


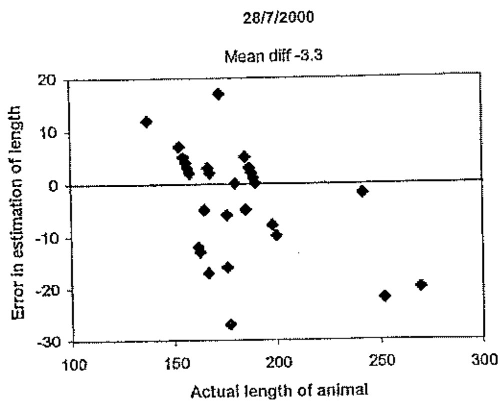












This series presents the scientific basis for stock assessments and fisheries management advice in South Australia. The documents contained in the series are not intended as definitive statements on the fisheries addressed but rather as progress reports on ongoing investigations.

Cuttlefish (*Sepia apama*)

D. McGlennon and K.C. Hall

November 1997

South Australian Fisheries Assessment Series No. 97/10

Cuttlefish (*Sepia apama*)

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1. EXECUTIVE SUMMARY

1. The fishery for cuttlefish (*Sepia apama*) has developed rapidly in South Australia over the past three years, with total catches increasing from 7.5 tonnes in 1993/4 to 255 tonnes in 1996/7.

2. The fishery is largely restricted to a small area near Pt Lowly in northern Spencer Gulf (Block 21), in shallow waters adjacent to the rocky shoreline. Less than 10% of the State catch is taken from other areas.

3. Fishing effort has increased 900% to 459 boatdays in 1996/7 in Block 21 and catch rates have also increased significantly to over 500 kg/boatday.

4. *S. apama* is distributed across southern Australia but there have been no fisheries related biological investigations on the species. Very little other biological information is available.

5. Other cuttlefish species studied around the world have very short life cycles with limited spawning frequencies per generation and subsequent mass deaths.

6. The rapid increase in catches from a restricted area have given rise to serious concerns about the sustainability of the fishery. Given the significant lack of biological knowledge of the species (but bearing in mind information on other species), management of the fishery should be conservative and adopt precautionary principles.

7. In the absence of known biological parameters for the species, and no knowledge of the relationship of the Pt Lowly population with others in South Australia, it is prudent to manage this population as a single stock which relies on its own successful annual spawning events to sustain itself. It is therefore recommended that fishing effort on the species during the spawning season be controlled.

8. An application has been made to the Fisheries Research and Development Corporation for funds to investigate *S. apama* in South Australia (primarily in the region of the fishery) and future research efforts are largely dependent on the outcome of that process.

2. INTRODUCTION

2.1. Overview

The cuttlefish (*Sepia apama*) fishery is a rapidly developing fishery in South Australia but is currently largely confined to a small area near Pt Lowly in northern Spencer Gulf. The population has been known to commercial and recreational fishers for many years but has mainly been exploited for bait in the past. In the past three years this situation has changed with a market being developed locally and interstate.

No fisheries related biological research has been conducted on the species in South Australia and information available on other cuttlefish species can only provide general indications of the life history it may have.

This report describes the commercial and recreational catch and effort history for the species. It also provides a literature summary of the general cuttlefish biology of other commercially important *Sepia* species. It provides the objectives of a research proposal to fully investigate the species in northern Spencer Gulf. This proposal has arisen out of concerns for the sustainability of the fishery.

2.2. Description of the fishery

The main fishery operates in a relatively small area near Pt Lowly and False Bay in northern Spencer Gulf (Block 21). Cuttlefish are caught by line and jigs in shallow waters close to the rocky shore in this area. Vessels used are typically 5 – 8 metres in length and are multi-purpose vessels used for other marine scalefish fishing.

Small quantities of cuttlefish were also caught using haul nets, gill nets and rock lobster pots in other coastal waters.

The recreational fishery for cuttlefish is largely as a by-catch for anglers targeting southern calamary (*Sepioteuthis australis*). The method of capture is also by line and jig.

2.3. Literature summary

2.3.1 Biology of *Sepia apama*

S. apama is the largest and most common cuttlefish in southern Australian waters. The maximum size recorded for the species was a mantle length (ML) of 490mm and weight of 6.2kg (Gales *et al*, 1993). However, the majority of adult cuttlefish recorded have only measured between 150 and 300mm ML. The distribution of the species is reported to extend across southern Australia from Ningaloo in Western Australia to Port Jackson in New South Wales, including northern Tasmania (Zeidler and Norris, 1989).

S. apama have been observed by both divers and fishermen to form localised aggregations in certain coastal areas during the winter months, for example the waters off Jervis Bay in NSW (Watson-Russell, 1981) and Whyalla in South Australia (Bramley, pers comm). These aggregations are believed to be spawning aggregations, possibly arising from the need for cuttlefish to attach their eggs to appropriate substrate following mating.

An honours project, conducted by Rowlings in 1994 is the only known scientific study ever to be undertaken on the biology of the *S. apama*. The project investigated the den ecology and behavioural interactions of *S. apama* in the waters adjacent to the Edithburgh jetty, in Gulf St Vincent. Male cuttlefish were observed to occupy and guard dens (rocky overhangs or caves within the reef structure). This behaviour has never previously been recorded for cuttlefish and is more akin to the common behaviour of octopi. Rowlings (1994), related this behaviour to the spawning activity of the cuttlefish. Males selected and guarded dens from April to August (coinciding with the spawning season). After mating with a male, the female layed her eggs a few days later deep within the males' den. The first eggs within a den were recorded in late July. The length of den occupancy varied from 6 to 96 days, with the time from den selection to egg deposition shortening as the spawning season progressed.

Rowlings (1994) also observed a sexual dimorphism in *S. apama* with respect to size. Male cuttlefish were larger than females with a mean mantle length of 230±52mm compared to 174±34mm for females. However, his sample size was very small (n = 43), from one location and sampled irregularly in time.

S. apama is thought to be semelparous, that is spawn only once in a lifetime, then die (Gales et al, 1993; Anon, 1993). Rowlings (1994) observed dead females under ledges soon after the deposition of eggs, and Gales *et al* (1993) found dead and moribund specimens of *S. apama* floating close to Tenth Island, in Bass Strait, Tasmania, in September. The local movement patterns of the wandering albatross (*Diomedea* sp.) have been attributed to the changing distribution of dying cuttlefish (as reported by local fishermen) in the Illawarra coastal region of New South Wales (Anon, 1993). Albatross and Australian fur seals (*Arctocephalus pusillus doriferus*) are both known to forage on cuttlefish in the months during and immediately following the spawning season (Gales *et al,* 1993), and are thought to be feeding on the post-spawning die-off.

In addition, large numbers of *S. apama* shells have been recorded washed up on beaches south of Sydney, along the Victorian coastline and in certain areas of South Australia during the late winter months, suggesting that large mortality events are occurring in adjacent waters at that time (Watson-Russell, 1981; Bell 1979; Hoffman, pers comm). This further supports the notion that large mortality events are occurring following the spawning season.

If *S. apama* is semelparous, as the evidence suggests, the impacts of overfishing in just one season, could have serious effects on the abundance of adult cuttlefish available to the fishery in subsequent years.

2.3.2. Biology of other commercial cuttlefish species

Although, the life history characteristics of cuttlefish tend to be quite species specific, and may vary greatly across its distribution depending upon the local environment, some common characteristics appear to exist and may be of some relevance to the fisheries biology of *Sepia apama*.

The majority of commercial cuttlefish species are demersal neritic species (see Table 1), inhabiting coastal and continental shelf waters in association with the substrate. Habitats range from rocky, sandy and muddy bottoms to seagrass beds, and coral reefs. Some species live in very close association with the substrate, eg. *S. esculenta,* who actually bury themselves within the sandy bottom during the day (Roper *et al*, 1984). *S. apama* is known to live in close association with temperate reef structures.

Table 1. Life history characteristics of the main commercial cuttlefish species of the genus *Sepia*.

Species	Common name	Major fishing countries	Max Size (DML/weight)	Size at Maturity	Habitat	Depth range	Spawning habitat	Spawning season	Spawning water temp
S. officinalis officinalis Linnaeus, 1758	Common cuttlefish	Western Europe, Mediterranean	450mm, 4kg (temperate); 300mm, 2kg (subtropical)	M: 60-110mm F: 110-250mm	demersal neritic; sandy muddy bottoms	coastline to 200m (more in upper 100m)	shallower water	all year, peak in summer	13-15°C
S. officinalis hierredda Rang, 1837	Common cuttlefish	NW Africa	440mm males; 370mm females	M: 120-140mm F: 135mm	demersal neritic	coastline to 120m	coastal waters	spring & autumn	17-25°C
S. elegans Blainville, 1827	Elegant cuttlefish	Western Europe, Mediterranean, NW Africa	65 males; 80 females	M: 25-50mm F: 30-60mm	demersal; muddy bottoms	40-430m	shallower water (40-70m)	all year; peak in spring - summer	13-18°C
S. orbigyana, Ferussac, 1826	Pink cuttlefish	Mediterranean, NW Africa	120mm	M: 40-50mm F: 70-80mm	nektonic; muddy bottoms	50-450m (most between 80-150m)	no onshore migrations reported	summer - autumn	
S. bertheloti, Orbigny, 1839	African cuttlefish	NW Africa	175mm males; 130mm females		demersal neritic; open bottoms	coastline to 160m (most between 70-140m)		summer - autumn	
S. esculenta Hoyle, 1885	Golden cuttlefish	Japan, Philippines, China, Hong Kong	180mm, 0.6kg		demersal neritic; sandy bottoms	10-100m	shallow coastal waters	spring - summer	13-16°C
S. latimanus Quoy & Gaimard, 1832	Giant cuttlefish	Japan, Philippines, SE Asia	500mm (largest known)		tropical coral reefs	to 30m		summer - autumn	
S. lycidas Gray, 1849	Kisslip cuttlefish	Japan, Hong Kong	380mm, 5kg		demersal neritic	15-100m	inshore shallow waters (15-30m)	spring	
S. pharaonis Ehrenberg, 1831	Pharaoh cuttlefish	India, Yemen, Northern Australia, Hong Kong	430mm males; 350mm females (smaller in subtropical)	M: 110-150mm F: 120-170mm	demersal neritic	coastline to 110m (more in upper 40m)	shallower water	all year, peaks in spring & autumn	18-24°C
S. aculeata Orbigny, 1848	Needle cuttlefish	India, Hong Kong	250mm, 1.3kg males; 200mm females	M: 70-130mm F: 90-170mm	demersal neritic	coastline to 60m	inshore (5-20m)	all year, peaks in spring & autumn	
S. prashadi Winckworth, 1936	Hooded cuttlefish	India, Red Sea	140mm		demersal	coastline to 40m			

Most species appear to undergo a migratory type of lifecycle. Temperate species tend to spend the winter in colder, deeper waters and migrate inshore during the spring and summer to spawn in the shallower, warmer coastal waters, eg. *S. officinalis officinalis* (von Boletzky, 1983). Whereas, subtropical and tropical species, eg. *S. officinalis hierredda*, tend to spend the summer in deeper cooler waters and migrate into coastal waters to spawn during the cooler seasons of spring and/or autumn (Bakhayokho, 1983). Although, mature individuals may be found all year round in a number of species, eg. *S. aculeata* and *S. pharaonis*, one or more "peaks" in spawning are usually observed, at times when optimal temperatures occur (see Table 1). Migration is thought to be undertaken in response to either changes in the water temperature and/or day length, and the pattern for one species may vary accordingly across the species distribution. *S. apama* appears to be migrating into coastal waters to spawn in winter (the opposite of other temperate species) in both the upper Spencer Gulf and Illawarra regions. However, this may vary in other areas of the Australian coastline according local temperature regimes. Mature specimens have been collected from Myponga in the Gulf St Vincent, in spring months (pers obs).

Cuttlefishes spawn relatively few, large, yolky eggs which the females attach to the substrate in clusters. Larger females usually spawn a larger number of eggs than smaller females, and the eggs themselves are usually larger in diameter. Substrate types suitable for attachment take on a variety of forms including algae, seagrasses, rocks, detritus such as dead branches, caves and reef structures, though each species tends to have a favoured form. It is thought that the necessity for suitable substrate for the attachment of eggs is what drives cuttlefish to aggregate in large concentrations in specific coastal areas for spawning. In most species no parental care of the eggs follows spawning. Rowlings (1994) found *S. apama* to lay eggs within dens, fiercely guarded by the male cuttlefish, an unusual scenario for cuttlefish.

The time taken for eggs to undergo embryonic development and hatch is highly dependent upon water temperature. The length of embryonic development for *S. officinalis officinalis* eggs varied from 40-45 days at 20°C to 80-90 days at 15°C in the laboratory (von Boletzky, 1983). Hatchlings of *S. apama* have been observed in the waters adjacent to Jervis Bay in September (Watson-Russell, 1981).

Juveniles closely resemble the adult form when hatched. Juvenile growth rates measured in aquaria have been strongly positively correlated to water temperature and food availability. The rapid growth rates observed at higher temperatures are thought to be due to a higher food intake. Even at high temperatures, young cuttlefish with a limited supply of food will maintain much slower growth rates.

For most species males attain a larger adult size than females (see Table 1). This also appears to be true for *S. apama* (Rowlings, 1994). This may be related to males either maintaining a higher growth rate during the adult phase (while female somatic growth declines in favour of reproductive development) or having a longer life span than females. *S. elegans*, was the only species found within the literature where females were recorded as reaching a larger size than males (Guerra and Castro, 1989), and having faster growth rates than the males.

The size of sexual maturity varies greatly for any given species between locations (eg. all species studied off the shores of India by Silas *et al* in 1985) and even within the same location. Richard (1971, from von Boletzky, 1983) found that high light intensities and long exposure times (ie. long day lengths) hampered sexual maturation in *S. officinalis officinalis*. Therefore he predicted that the onset of maturation did not commence until juveniles had migrated into deeper darker waters, and that the time to and size at sexual maturity was largely determined by the length of time juveniles spent under optimal growth conditions within the warmer inshore waters before migrating to the deeper cooler waters. Not all cuttlefish of the one species in the one area are thought to migrate at the same time.

Sex ratios vary greatly with time of year and from location to location, but are rarely the expected 50:50 ratio for any species. Equally rarely, however, does either sex consistently dominate (eg. Rao *et al*, 1993: Nair *et al*, 1993). Differing life spans and life history strategies between the two sexes may account for these differences in sex ratio. For many species it is thought that females die following spawning, whereas, males may live through a number of spawning seasons. It is highly unlikely that large males of greater than 300mm in length could attain those sizes in less than 2 years, given growth rates that have been estimates to date. However, only through the development of an appropriate ageing technique will this question of longevity be fully answered.

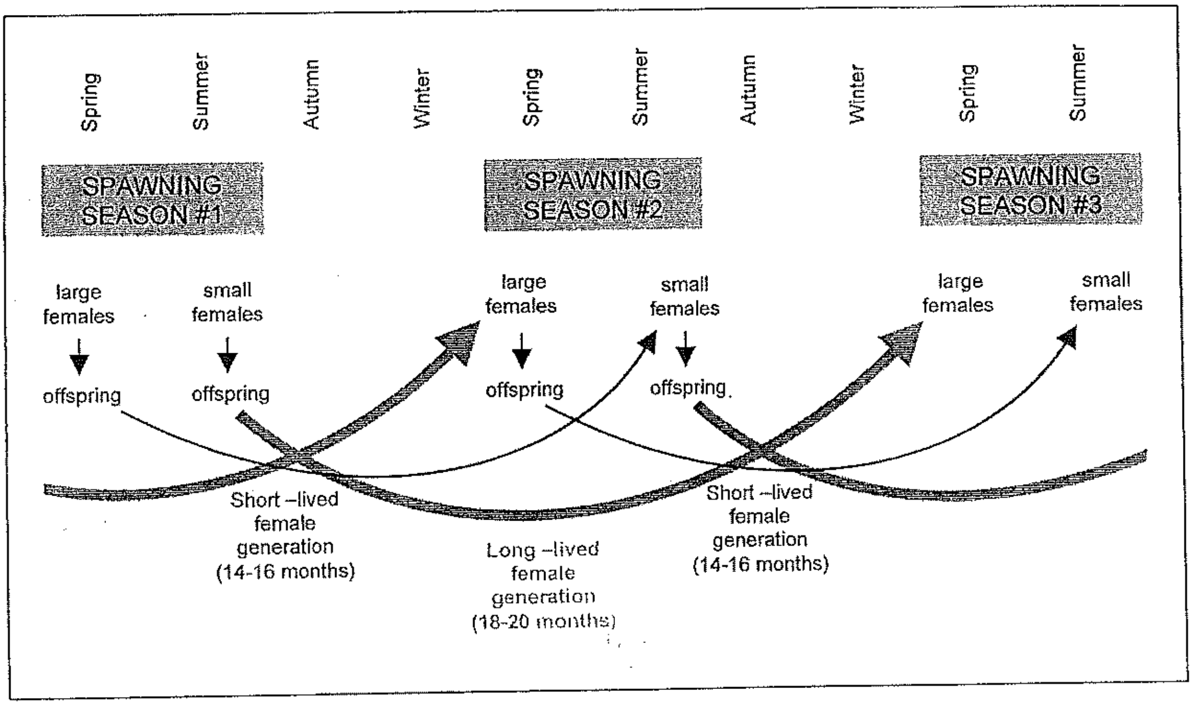
There appears to be a large degree of flexibility displayed in the life cycle of cuttlefish species, and in particular between the sexes of any given species. For example, von Boletzky (1983) proposed two alternating life cycles for females of *S. officinalis officinalis,* one short generation (just over a year) followed by a longer generation (almost 2 years) (Fig. 1). A later field study by Le Goff and Daguzan (1991) confirmed that this was the case for the species off the coasts of Brittany, France.

Large mature females were found to migrate into the spawning grounds first, early in the spring, followed later by smaller mature females in the summer. Juveniles spawned by the larger females early in the spawning season were thought to grow rapidly over the summer and then mature the following winter to become the smaller females (approx 14-16 months old) spawning late in the following season. Whereas those juveniles spawned late in the season by the smaller females would miss the next spawning season and become the large females (approximately 18 month old) spawning early in the subsequent season. Males, however, were possibly spawning each year, through several seasons before dieing. Similar alternative life cycle strategies have been proposed for both *S. pharaonis* (Aoyama and Nguyen, 1989) and *S. officinalis hierredda* (Bakhayokho, 1983).

The catch gradings given for *S. apama* in Section 3.1.5., suggest that a similar migration pattern, ie. larger females migrating to the spawning grounds first in the spawning season followed by smaller females later in the season, may be occurring in the Pt Lowly fishing grounds. However, the pattern observed may also be an artefact of a differing catchability for different sized cuttlefish, and the catches have no separation according to sex.

The flexibility of life cycle displayed by cuttlefish and the apparent ability to match their life cycle to local conditions, poses some interesting questions with respect to appropriate management. Within the one population there may be individuals undergoing a number of different life cycles at the same time, and these life cycles may vary across the species distribution depending upon local environmental conditions. Therefore, management in different regions would depend upon the determination of local scenarios for each species and sex.

Fig. 1. Diagrammatic representation of the alternating life cycles of female *S. officinalis officinalis*.



3. REVIEW OF FISHERY

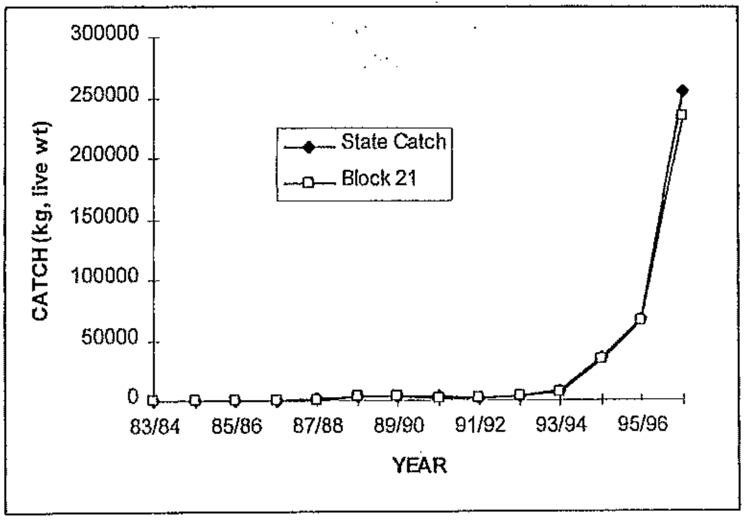
3.1. Commercial fishery catch and effort

3.1.1. Catch

The commercial fishery for cuttlefish was very limited until 1993/4 with State catches of less than 10 tonnes (Fig. 2), the majority of which was taken in Block 21 in northern Spencer Gulf. The last three years have seen catches increase rapidly to a reported catch of 255 tonnes in 1996/7. Until 1995/6, Block 21 produced almost all of the cuttlefish catch but in 1996/7 an additional 21 tonnes was produced in other waters of Spencer Gulf (primarily Blocks 22, 23 and to a lesser degree 33).

The value of the catch has risen from $45,100 in 1994/5 to $334,712 in 1996/7.

Fig. 2. Commercial cuttlefish catches for South Australia and Block 21 for 1983/4 to 1996/7.

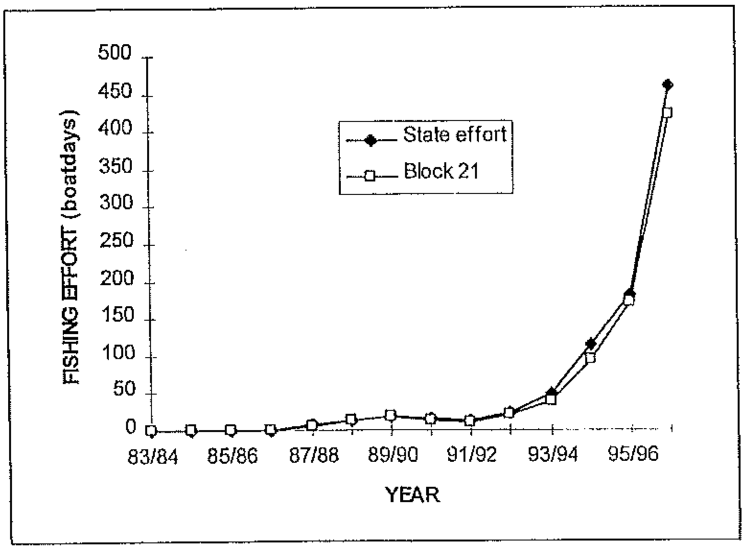


3.1.2. Effort

Reported fishing effort has increased from less than 50 boatdays per year prior to 1993/4 to 459 boatdays in 1996/7 (Fig. 3). Again, this effort was primarily expended in Block 21.

The current information provided by fishers on fishing effort (boatdays) is insufficient to indicate the influence of increasing skill by fishers on temporal changes in effective effort.

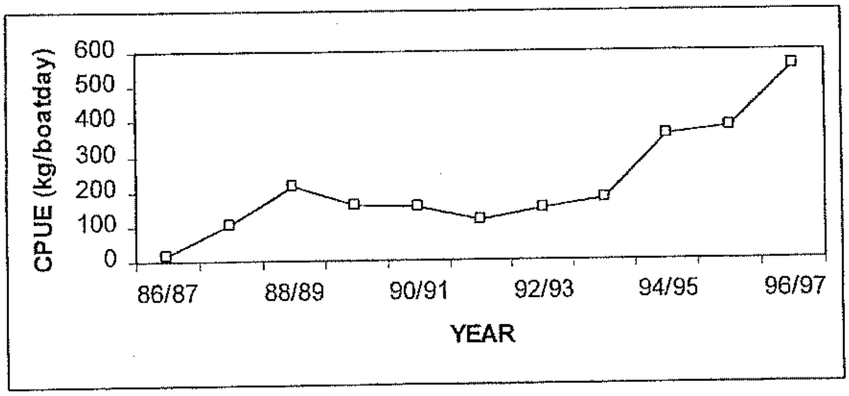
Fig. 3. Commercial targeted fishing effort for cuttlefish from 1983/4 to 1996/7.



3.1.3. CPUE

Catch per unit effort (CPUE) in Block 21 remained relatively stable (at very low effort levels) until 1993/4 after which it has climbed significantly each year (Fig. 4). The CPUE in 1996/7 reached 556 kg/boatday. Due to the coarseness of fishing effort data (Section 3.1.2.), the reasons for the high CPUE in 1996/7 are not known.

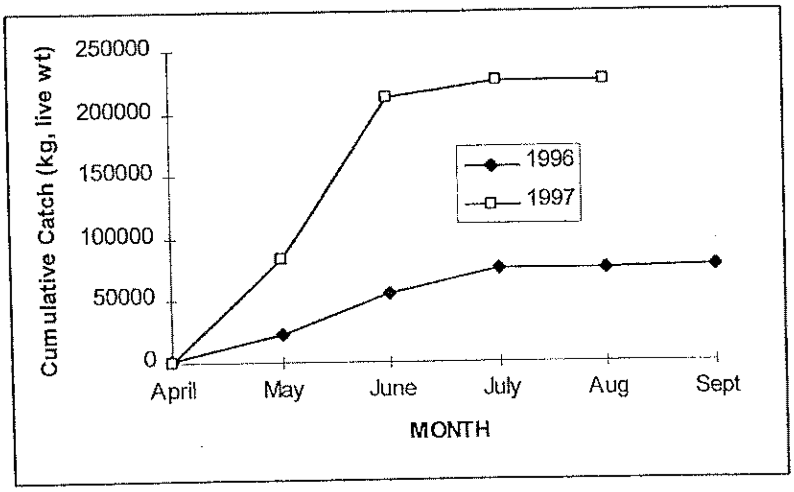
Fig. 4. Catch per unit effort (kg/boatday) for cuttlefish in Block 21.



3.1.4. Monthly catches

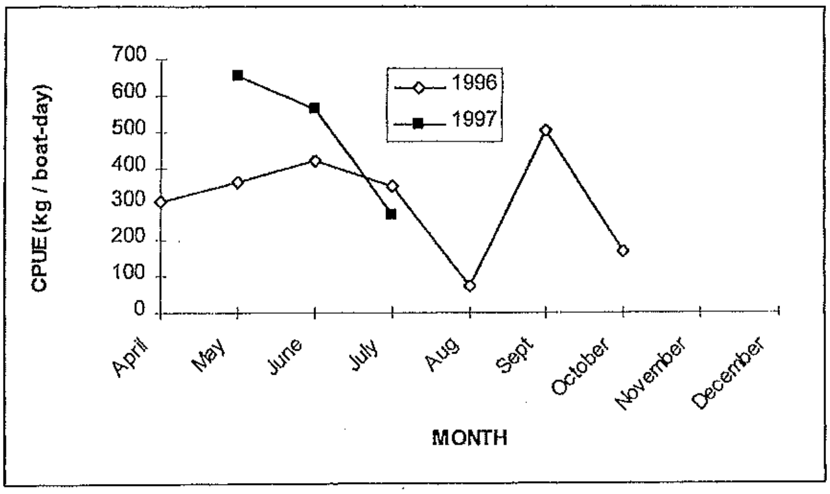
The fishery in Block 21 is shortlived, starting in April/May and peaking in June (Fig. 5). Some fishing continues into July but little catch is taken after this time.

Fig. 5. Monthly catches of cuttlefish from Block 21 in 1996 and 1997.



Monthly CPUE varied between 1996 and 1997 (Fig. 6). The pattern in 1996 was a steady rise from April to June to a high of 416 kg/boatday, followed by a significant decline by August. The subsequent rise is misleading as it is based on only 2 boatdays fishing effort. In 1997, CPUE started at a high of 650 kg/boatday in May but declined rapidly by July after which little fishing occurred.

Fig. 6. Monthly CPUE for commercial cuttlefish catches in Block 21 in 1996 and 1997.

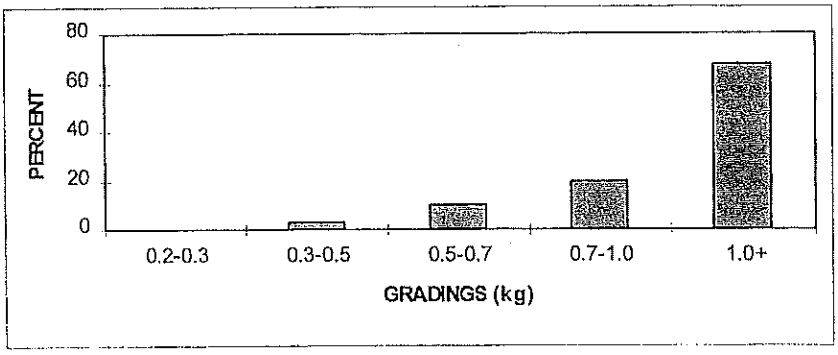


3.1.5. Cuttlefish size

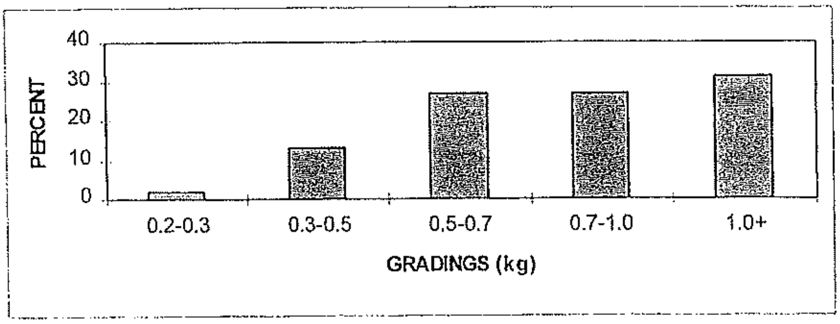
Gradings of cuttlefish sold were obtained from one processor for fortnights between 16/5/97 and 7/7/97 (Fig. 7). These gradings show a predominance of large (1+ kg) fish in the first fortnight. However, the relative importance of these large cuttlefish declined quickly in following fortnights.

Fig. 7. Fortnightly gradings of cuttlefish purchased from Block 21, May – July 1997.

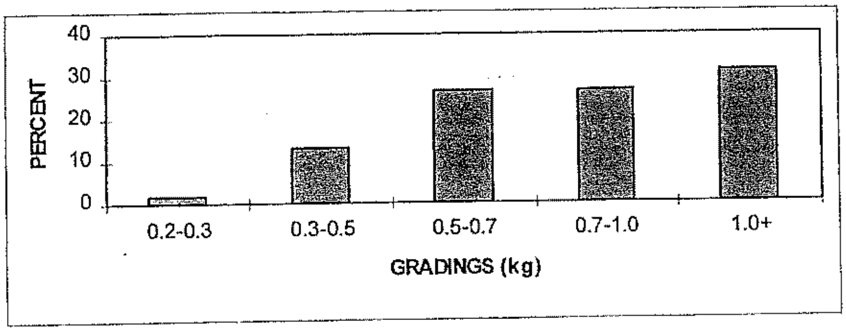
a) fortnight from 16/5/97



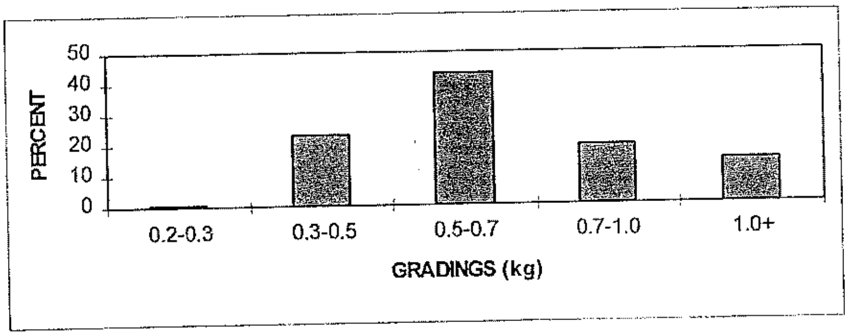
b) fortnight from 30/5/97



b) fortnight from 14/6/97

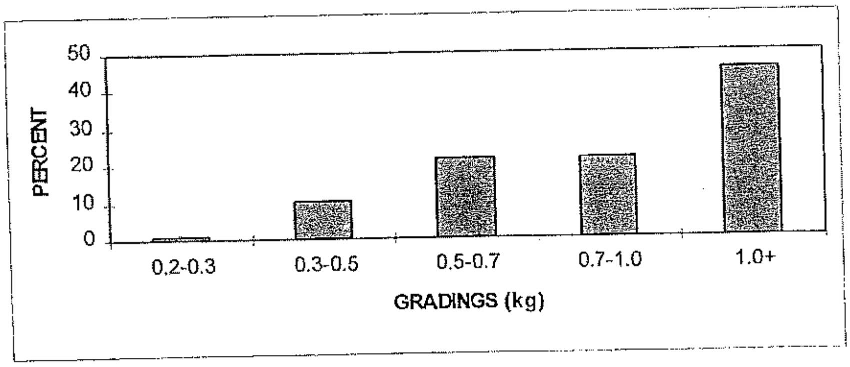


d) fortnight from 28/6/97



The gradings of all cuttlefish (fortnights combined) show nearly 50% were greater than 1 kg (Fig.8).

Fig. 8. Total gradings of cuttlefish purchased from Block 21, May – July 1997.



Mean size was not possible to calculate as no data were available on the average size of the 1+ kg cuttlefish.

3.1.6. Fish processor returns

A significant discrepancy exists between reported catches from fishers' returns and from fish processors' returns detailing purchases. In May and June 1997 (the main catching months), 212.7

tonnes was reported caught in Block 21 alone but processors have reported only 136.8 (64%) tonnes were purchased in South Australia.

Fishers' returns indicate that cuttlefish were also retained for personal use and bait, and were sold privately. Due to the structure of catch returns, it cannot be established whether these other uses equate to the discrepancy between overall catches and processor purchases.

The value of the fishery is calculated on average price per kilogram multiplied by total catch. In this case, the value may be substantially overstated if the 75 - 80 tonnes not recorded by fish processors was used as bait.

3.2. Recreational catch and effort

A comprehensive survey of marine recreational boat fishing was conducted between 1994 and 1996 (McGlennon and Kinloch 1997). Cuttlefish were recorded as a small component of the recreational harvest (those fish caught and retained) from the 3,513 interviews recorded.

39 (0.11% of all fish) cuttlefish were recorded in the catches of Gulf St Vincent anglers. The total harvest of all fish was estimated at 1,994,962 for Gulf St Vincent, which by proportion would include approximately 2,200 cuttlefish. There was no apparent seasonality to the catches. The majority were caught in southern Gulf and metropolitan waters.

122 (0.47%) cuttlefish were recorded in Spencer Gulf catches. The total harvest of all fish was estimated at 1,526,350 for Spencer Gulf, which by proportion would include approximately 7,200 cuttlefish. Again, they were caught in all months. Approximately 50% were caught in Block 21 in northern Spencer Gulf but this was largely caused by a single trip which yielded 40 cuttlefish. The remainder were caught in all areas of the Gulf.

Only 7 of the 90 trips which caught cuttlefish had nominated them as a target species. The species should therefore be generally viewed as by-catch in the recreational fishery, usually when anglers are targeting southern calamary (*Sepioteuthis australis*).

No cuttlefish were recorded outside of Gulf waters.

3.3. Other sources of fishing mortality

An analysis of by-catch in the Spencer Gulf prawn trawl fishery reported two unidentified species of cuttlefish making up 0.157% and 0.006% of the total catch (Carrick 1997). The numbers caught from 32 trawl stations were 134 of species 1 and 5 of species 2.

The identification of the species is needed before further discussion is warranted, although it would appear that the impact of the prawn fishery on cuttlefish may be limited.

4. RESEARCH

There has been no fisheries related biological investigations of cuttlefish in South Australia.

The rapid rise in commercial catches in northern Spencer Gulf has led to pressure to initiate such an investigation. To this end, an application has been submitted to the Fisheries Research and Development Corporation (FRDC) for a three year study with the following objectives:

- To establish the general life history characteristics of *S. apama* in South Australian waters, including growth, age and reproductive biology.
- To independently estimate the abundance of cuttlefish in the Pt Lowly fishing grounds and its relationship to the commercial and recreational catch.
- To investigate egg densities, recruitment and the relationship with adult abundance, timing of spawning and its interaction with the fishery.
- To investigate the structure and seasonal movement patterns of the exploited population and its relationship with other known populations in South Australian waters.
- To investigate marketing strategies aimed at increasing the value of the current cuttlefish product and/or identifying alternative value-added products.

The project proposal has received support from the Marine Scalefish Management Committee and the Fisheries Research Advisory Board and was formally submitted to FRDC on 28/11/97.

The level of research into this species in South Australia is dependent on the support of FRDC with this proposal.

In addition, there is a need to collect more precise fishing effort data to assist in explaining fluctuations in CPUE.

5. MANAGEMENT IMPLICATIONS

The rapid increase in commercial catches of cuttlefish from a small area near Pt Lowly has raised considerable concern about the sustainability of the fishery. Local opinion has suggested that the population size has already been considerably reduced.

The species is currently available to all licensed Marine Scalefish fishers and the number targeting the Pt Lowly population has increased in each of the last 3 years. Because of the high daily catch rates, the publicity this fishery has attracted and the ease of access to the population, it is likely that effort will continue to increase. This is even more likely if market development occurs and unit prices increase.

Although very little is known about this species, information on other cuttlefish species suggests that this species may be very short-lived, have fast growth and rely on few (maybe 1) spawnings per generation. If this is the case with *S. apama*, the population may rely on adequate spawning success each year to sustain itself.

In the absence of known biological parameters for the species, and no knowledge of the relationship of the Pt Lowly population with others in South Australia, it is prudent to manage this population as a single stock which relies on its own successful annual spawning events to sustain itself.

The fishery is believed to target cuttlefish during a spawning aggregation. It would therefore be considered prudent to manage fishing effort on the species during the spawning season. Given the constraints of very limited biological knowledge, several alternatives are available:

- a total allowable catch from the fishery during spawning season (or part of it)
- daily quotas per fisher during the spawning season (or part of it)
- limited access to control fishing effort during the spawning season (or part of it)
- a seasonal closure defined around Pt Lowly during the spawning season (or part of it)

The proposed FRDC study will provide many of the details which would need to be defined for any of these management measures to be successful eg. timing and duration of spawning and biomass estimate. However, this work will not commence in time to have even preliminary results available for the 1998 fishing season. It is recommended that a precautionary approach be adopted for 1998 with full review at the end of 1998 ie. in the 1998 stock assessment report.

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South Australian Fisheries Assessment Series No. 98/9

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Cuttlefish (*Sepia apama*)

KC Hall
University of Adelaide and SARDI Aquatic Sciences
and
D McGlennon
SARDI Aquatic Sciences

November 1998

This series presents the scientific basis for stock assessments and fisheries management advice in South Australia. The documents contained in the series are not intended as definitive statements on the fisheries addressed but rather as progress reports on ongoing investigations.

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Acknowledgments

The research findings presented in this report were funded by an Australian Postgraduate Award scholarship through the University of Adelaide in collaboration with SARDI Aquatic Sciences and a research grant from the Fisheries Research and Development Corporation.

Sincere thanks to Sangeeta Taylor, Paul Jennings, Bruce Jackson and Dave Short for assistance in the field and postgraduate supervisors Dr Tony Fowler and Associate Professor Mike Geddes for sampling design advice.

Catch and effort data for the fishery were supplied by the commercial marine scalefish licence holders through the SARDI Aquatic Sciences Statistics Department.

1. EXECUTIVE SUMMARY

The South Australian commercial cuttlefish (*Sepia apama*) fishery was again dominated by catches in northern Spencer Gulf. Catches in the region between Point Lowly and Black Point represented 98% of the State catch, but reported a fall from 240.7 tonnes in 1997 to 145.7 tonnes in 1998. This decline is considered to result from a combination of reduced population size and restricted fishing access. Despite the decline, the reported catch is the second highest recorded.

The fishery opened in late April with the arrival of the first cuttlefish to the area and continued until May 15 when commercial fishers introduced a voluntary 10 day closure due to low catch rates. The fishery re-opened for approximately 16 days and was then legislatively closed on 11 June due to concerns about the sustainability of the population under observed fishing activity.

Biological aspects of the cuttlefish population were studied every 3-4 weeks from March to September, 1998. Investigations included:

- Diver based:
  - Mapping of the habitat within the Fitzgerald Bay to False Bay area, as well as the BHP wall
  - Description and estimation of relative areas of different habitat type
  - Utilization of habitat type by cuttlefish
  - Estimates of cuttlefish abundance and biomass in areas open and closed to fishing
  - Estimates of cuttlefish abundance and biomass through the fishing season
  - Length frequency and sex ratio estimates
  - Observations of predation on eggs and juveniles

- Biological sampling for laboratory based analyses of:
  - Length-weight relationships
  - Preliminary ageing techniques
  - Reproductive biology
  - Assessment of condition indices
  - Temperature dependent development of eggs

As this was the first year that the biology of *S. apama* has been studied, treatment of these results should acknowledge that this is work in progress and represents our current understanding. The key findings were:

1. estimated spawning biomass has declined significantly even when compared with the previous years reported catch (from more than 260 tonnes reported as catch in 1997 to approximately 199 tonnes estimated as total biomass in 1998)

2. immigration into the spawning area begins in late April and continues for at least 4 weeks (but may continue longer)

3. spawning appears to take place from late April through to August with no peak in activity yet determined

4. individual females probably spawn more than one batch of eggs per season and possibly over an extended period of time

5. no loss of condition (indicative of senescence) could be detected in animals towards the end of the spawning season and therefore may be returning in subsequent years

6. more than one age class of each sex may be present in the spawning aggregation

7. the closed area initially used in 1998 protected about 45% of the reef area but only 20% of the observed biomass (bearing in mind movement between the open and closed areas is not yet understood)

8. the fishery is capable of rapidly depleting the available biomass, even with few operators present

9. the catch is initially biased towards large animals (probably through cuttlefish behaviour rather than fisher behaviour)

10. the catch is biased towards females resulting in a highly unbalanced sex ratio in the fished population.

Management Implications

It is recommended that whatever management action is taken in 1999, a conservative management strategy be formulated which recognises the vulnerability of this population to intensive fishing effort. Successful stock rebuilding will exacerbate current interest in the fishery, particularly if better marketing strategies can be developed.

To this effect it is recommended that:

- in the event that the fishery in the Black Point to Point Lowly region remains open to the taking of cuttlefish during the 1999 spawning season, a management strategy be adopted to allow for at least 70% escapement in 1999 to facilitate stock rebuilding

and

- consideration be given to complete protection should pre-fishing biomass estimates in 1999 show evidence of further population decline.

2. INTRODUCTION

2.1. *Overview*

A small fishery targeting the giant Australian cuttlefish (*Sepia apama*, Gray) has existed in South Australian waters for over ten years. Until recently, the species was targeted primarily for use as bait, by only a small number of marine scalefish fishers, and reported catches were very small (less than 4 tonnes per annum). However, the development of an export market for the species in recent years, has resulted in a rapid rise in the number of fishers targeting the species. Reported catches have risen dramatically as a result, with 262 tonnes reported in 1997.

At present the majority of the catch is taken from one small area of coastline near Black Point in the northern Spencer Gulf. Every winter thousands of cuttlefish aggregate over the shallow fringing reef in this area in order to spawn. No other aggregation of such large numbers is known to occur anywhere else across the species distribution, which covers southern coastal waters from Ningaloo in Western Australia to Port Jackson in New South Wales. Neither is the species currently targeted anywhere else in Australia.

Prior to 1998, no management restrictions specific to the taking of cuttlefish had ever been introduced in South Australia. However, the recent increases in the level of exploitation on the spawning aggregation at Black Point have raised strong concerns over the sustainability of the fishery in the Black Point area.

In order for appropriate management controls to be introduced, basic biological information for the species is required. Unfortunately, little is known about the biology of *S. apama*. Despite its large size and common occurrence in southern Australian waters, it has previously attracted little scientific interest. As a result a three year Fisheries Research and Development Corporation (FRDC) funded project was initiated to investigate the general life history of *S. apama* in South Australian waters, and gather baseline biological data upon which the impacts of fishing on this species may be assessed and any necessary management controls may be based.

This is the second stock assessment report for S. *apama,* in South Australia. The first report (McGlennon and Hall, 1997) briefly described the fishery and reviewed historical catch and effort data collected from the commercial fishery. It also provided a summary of the scientific literature pertaining to the biology of *S. apama* and other commercially important *Sepia* species. The objectives of the proposed FRDC project were also outlined.

This second stock assessment report will outline the new management controls introduced in 1998 for the taking of cuttlefish in South Australian waters and report on the research results obtained during the first year of the three year research project.

2.2. *Description of the fishery*

The main fishery targeting *S. apama* operates in a very small area (approximately 8 km of coastline) between Point Lowly and Black Point in northern Spencer Gulf (Block 21) (Figures 1 and 3). Cuttlefish are targeted using lines and squid jigs in shallow waters (< 8m deep), close to the rocky shore. Vessels used in the fishery are generally the multi-purpose vessels used for other marine scalefish fishing, typically 5-8 meters in length. Up to 4-5 fishers operate from the one vessel. The use of larger sleeping vessels in combination with smaller dinghies was observed in the 1998 season.

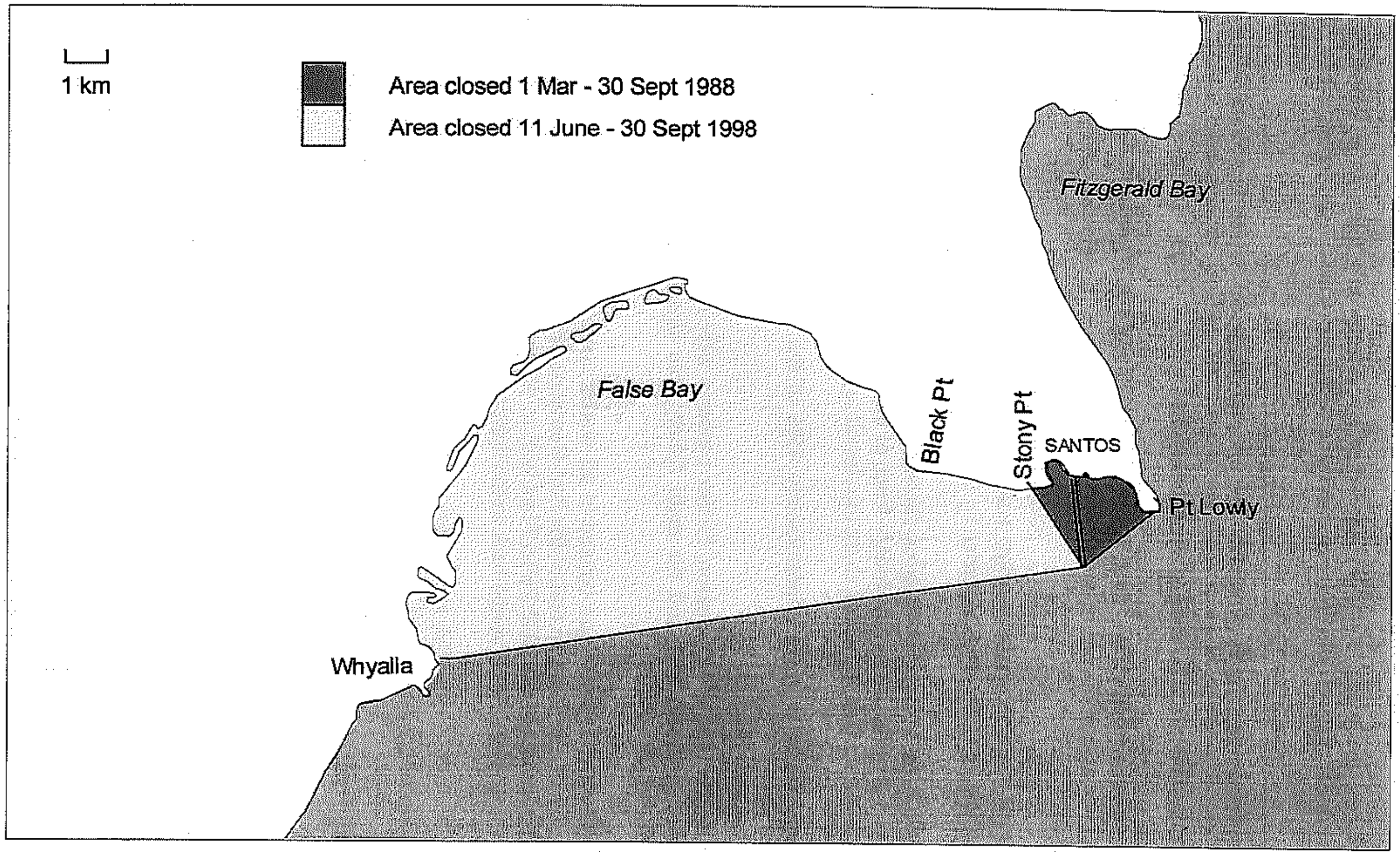


Figure 1. Map detailing the original area closed to cuttlefish fishing in 1998 (1 Mar - 30 Sept) and the subsequent area closed to fishing (11 June - 30 Sept) in northern Spencer Gulf near Whyalla.

The remainder of the cuttlefish catch reported by commercial fishers in South Australia is usually taken as by-catch by squid jigs and lines, and in haul nets, gill nets and rock lobster pots, throughout the State.

Recreational fishers rarely target cuttlefish and they are usually only taken as by-catch by anglers targeting southern calamary (*Sepioteuthis australis*) as both species are caught using similar lines and jigs.

The cuttlefish fishery in South Australia is currently managed under the broad management framework of the commercial marine scalefish fishery. Previously, there have been no specific management controls in place for the taking of this species.

Prior to the commencement of the 1998 fishing season, a time and area closure within the main spawning ground was introduced, in an attempt to protect some of the spawning population in the Point Lowly area.

From 1 March 1998 to 30 September 1998, it was unlawful for any person to engage in any fishing activity within Spencer Gulf waters enclosed by the following boundaries:

> From the Point Lowly lighthouse to the southern end of the Port Bonython jetty, then to the seaward end of the western boundary fence of the SANTOS facility, and from there following the high water mark eastwards along the shoreline back to the lighthouse (Figure 1).

This closure was found to cover approximately 45% of the reef habitat in the known spawning grounds.

However, during the 1998 fishing season, further concerns were raised regarding the level of fishing effort being exerted in the area, and the main fishery was closed on 11 June 1998 until the 30 September 1998.

> The taking of cuttlefish was banned in all waters enclosed by a line from the Point Lowly lighthouse, to the southern end of the Port Bonython jetty and south west across False Bay to the southern end of the BHP Pellet Plant wall at Whyalla. Then from there following the high water mark along the shoreline back to the lighthouse (Figure 1).

A recreational limit of 15 cuttlefish per person, and 45 per vessel was also introduced in June 1998, at the time the main fishery was closed.

Management conditions for the 1999 fishing season have yet to be finalised.

2.3. Literature review

No new scientific literature regarding the biology of *S. apama* was published in 1998. A summary of previous literature can be found in the first stock assessment report produced for this species (McGlennon and Hall, 1997).

A popular article in *Southern Fisheries* (Hall, in press) briefly described some underwater observations made on the spawning behaviour and biology of the spawning aggregation at Black Point during the first year of the three year research project.

3. REVIEW OF FISHERY

3.1. *Commercial fishery catch and effort*

3.1.1. Catch

The total annual catch of *Sepia apama* taken by the commercial fishery in South Australia is shown in Figure 2. The total catch produced from Block 21 is also included, as catches from Block 21 account for the majority (92-98%) of the total State catch (Table 1). Note that catch and effort data for this species refer to calender years, in contrast to the general reporting of financial years. This is done to more accurately represent the main fishing season of April to July each year for this species. For this reason, 1998 data are provisional and only refer to catches reported until the end of June 1998. The total catch (as compared to the targeted catch) includes cuttlefish taken as by-catch as well as those taken by fishermen as the target species.

The highest annual total catch of *S. apama* was recorded for South Australia in 1997, with 262 tonnes taken by 63 licence holders. In 1998, a considerably smaller catch of 149 tonnes was reported, taken by 51 licence holders. The sudden drop in catch from 1997 to 1998 can be attributed to the early closure of the main fishery in Block 21 during the second week of June. However, even with the early closure being introduced, the 1998 catch was still almost double the 1996 catch of 83 tonnes.

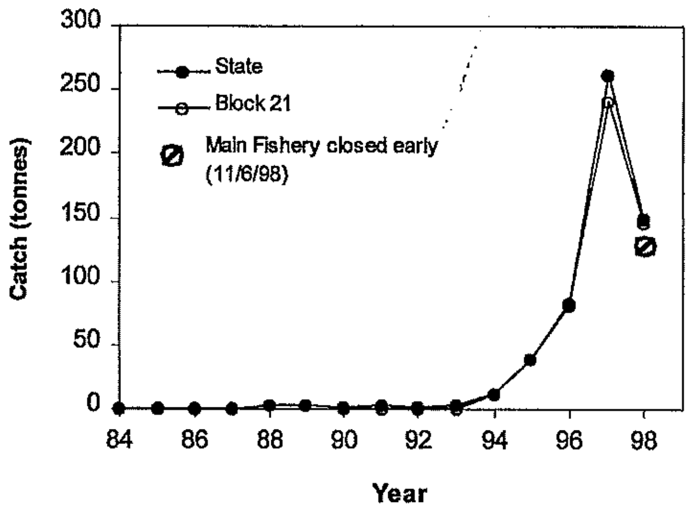


Figure 2. Annual total commercial catch of cuttlefish for South Australia and Block 21. (1998 data is provisional only).

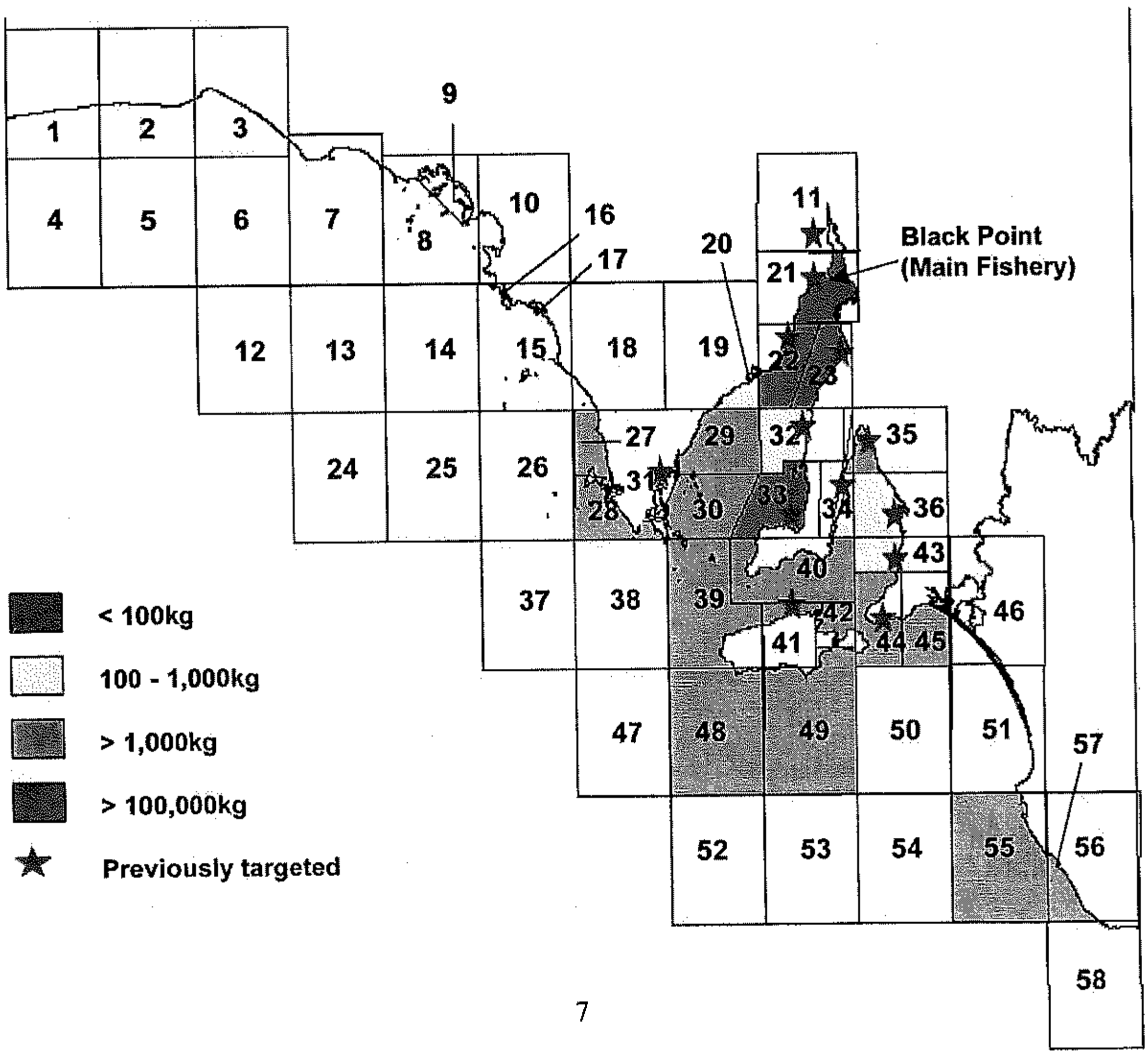
The number of licence holders targeting cuttlefish in South Australia remained around 15 from 1994 to 1996, however the targeted catch increased from 11 tonnes in 1994 to 36.6 tonnes in 1995 and 77.3 tonnes in 1996 (Table 1). Then in 1997 the number of fishermen targeting cuttlefish doubled to 33, but the targeted catch increased by over 3 times to 254 tonnes.

Only about half of the licence holders reporting catches of cuttlefish within the State, have been actively targeting cuttlefish, and virtually all of these were targeting cuttlefish in Block 21 (Table 1). Therefore, virtually all (99-100%) of the targeted catch was reported from Block 21, except in 1997 when 7% of the targeted catch was produced from elsewhere in the State. This was primarily from Blocks 22 and 23, and to a lesser extent Block 33 (Figure 3).

Table 1. **Comparison of total catch, targeted catch and number of licence holders for South Australia and Block 21.** (1998 data is provisional only).

	Total Catch					Targeted Catch				
	State		Block 21			State		Block 21		
Year	Catch (tonnes)	No. of Fishers	Catch (tonnes)	No. of Fishers	% of State Catch	Catch (tonnes)	No. of Fishers	Catch (tonnes)	No. of Fishers	% of State Catch
94	12.4	34	11.6	8	94%	11.0	14	10.9	8	99%
95	39.9	38	38.6	10	97%	36.6	15	36.3	10	99%
96	82.6	48	80.9	14	98%	77.3	15	77.2	13	100%
97	262.1	63	240.7	28	92%	253.5	33	235.5	28	93%
98	148.8	51	145.7	25	98%	145.8	27	145.5	24	100%

Figure 3. **Fishing blocks where cuttlefish have been targeted or catches have been reported (with general magnitude of catch indicated by color), in last 10 years.**



3.1.2. Effort

Reported fishing effort in the commercial fishery, displays a similar trend (Figure 4) as that observed in the total catch data. Fishing effort declined from a peak of 919 man days in 1997, to 525 man days in 1998, following the early closure of the main fishery in the second week of June. Effort expressed as man days is calculated by the multiplying the number of boat days recorded by each licence holder by the number of fishers operating from each vessel on any given day.

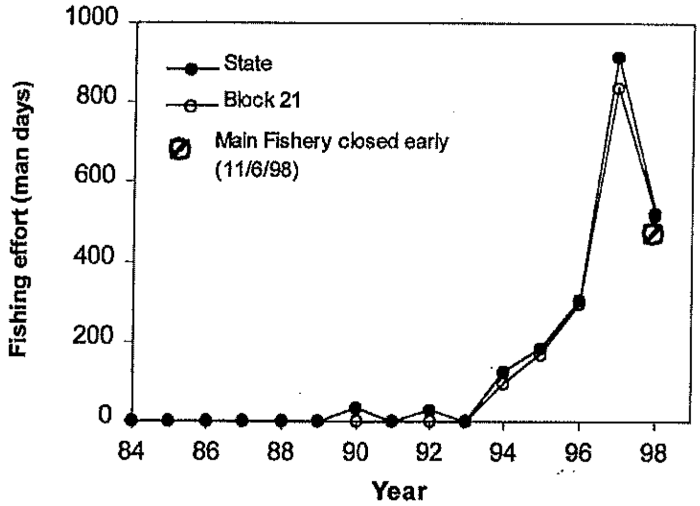


Figure 4. Annual commercial targeted fishing effort for cuttlefish in South Australia and Block 21. (1998 data is provisional only).

In 1998, fishing in the main fishing grounds (waters adjacent to Black Point in Block 21) commenced on 29 April, and continued for around 16 days. By the end of the second week in May, catch rates had declined to an uneconomic level, so licence holders introduced a 10 day voluntary closure on 15 May. Fishing resumed officially on 25 May (however, processor records indicate that some fishing may have occurred as early as 22 May) and continued for another 16 days, before the main fishery was officially closed on 11 June.

Therefore, the main fishery was effectively only operating for about 32 days in 1998.

3.1.3. CPUE

Catch per unit effort data (CPUE) is provided for Block 21only (Figure 5), as the targeted catch in Block 21 accounts for virtually all of the State targeted catch. Prior to 1994 CPUE data are confidential as less than 5 licence holders were involved.

CPUE increased dramatically from 115 kg/man day in 1994 to 215 kg/man day in 1995. Further increases in CPUE were recorded in 1996 and 1997. In 1998, CPUE was the same as that in 1997, with 280 kg/man day recorded.

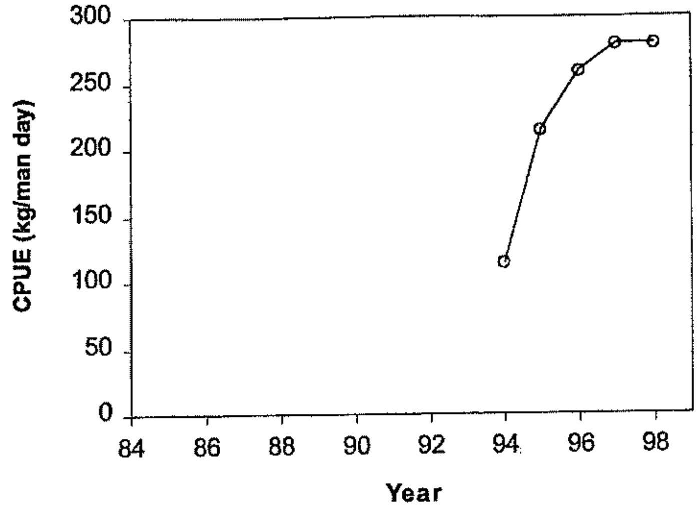


Figure 5. **Catch per unit effort for cuttlefish targeted in Block 21.**
(Data for 1998 is provisional only)

3.1.4. Monthly catch and effort

Figure 6 represents the cumulative catch produced from Block 21 as the fishing season progressed, for the last three years.

In 1996, there was a gradual accumulation of the catch throughout the season from May through to July. Whereas, in 1997, intense fishing pressure was exerted earlier in the fishing season, with the bulk of the catch taken in the first two months.

In 1998, over 100 tonnes was taken in the first month of fishing (May) which was even more than in 1997. However, the fishery was closed in the second week of June, and cumulative catch was therefore truncated.

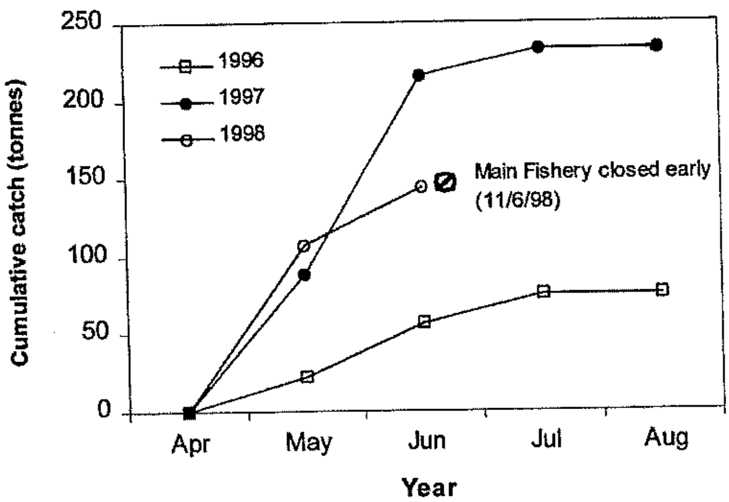


Figure 6. **Monthly cumulative targeted catch of cuttlefish from Block 21 for the last 3 years.**
(1998 data is provisional only).

The pattern in monthly CPUE for Block 21 also varied over the last three years (Figure 7). In 1996, the CPUE rose from May to a peak in June (296 kg/man day) and then declined again in July. Whereas, in 1997, the CPUE in May was much higher to begin with (320 kg/man day), declined slightly in June and then plummeted in July (165 kg/man day). In 1998, the initial CPUE in May (297 kg/man day) was lower than in 1997, and further declined in June, at which time the fishery was closed.

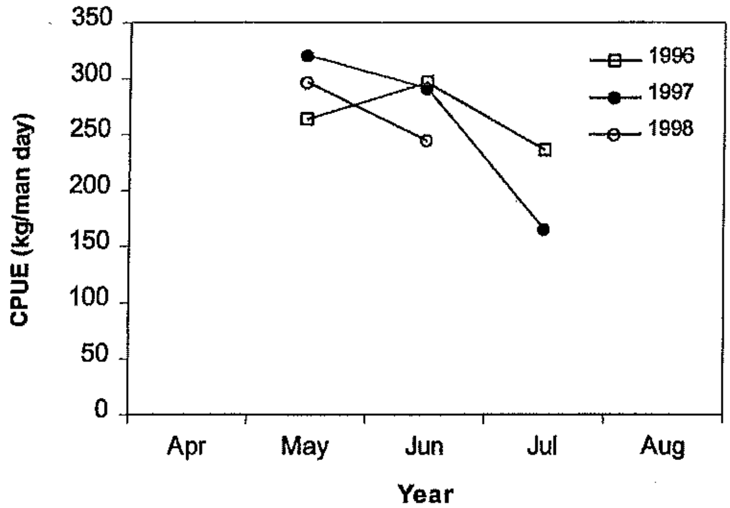


Figure 7. Monthly CPUE for targeted catches of cuttlefish in Block 21 for the last 3 years. (1998 data is provisional only).

3.1.5. Distribution of catch between licence holders

The majority of the catch in South Australia is taken by a small proportion of the total number of licence holders in the State (Table 2). This was particularly evident in 1997. Seven licence holders reported catches of over 15 tonnes, with their combined catch adding up to 150 tonnes. This accounted for 57% of the total State catch in 1997, but compares to the entire State catch in 1998 of 149 tonnes. Therefore, placing a limit on the number of licence holders able to participate in the fishery is unlikely to have much impact on the overall catch taken, if introduced alone.

3.1.6. Size structure of catch

Size gradings of cuttlefish sold to one processor are displayed in Figure 8 (each individual graph i-vii represents one week of the fishing season). These gradings show a predominance of large (1kg+) fish taken in the first and second weeks of the main fishing season. In the remaining 4 weeks of the season, the different size classes are more evenly caught with slightly more 5-700 g fish. This suggests that the largest fish are either arriving in the area first or are being selectively caught first. Either way, the largest fish are being removed early in the spawning season.

Unfortunately, it cannot be determined from processor records, what proportion of each sex is present in the largest size class of fish.

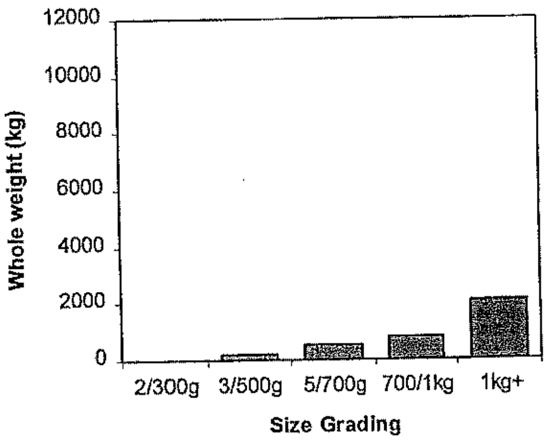
Table 2. **Distribution of total catches of cuttlefish in South Australia between licence holders for the last three years.** (1998 data is provisional only).

Catch Range		1996	1997	1998
< 5 tonnes	No. licence holders Combined catch % of total catch	42 19 tonnes 23%	46 28 tonnes 16%	38 24 tonnes 16%
5 – 15 tonnes	No. licence holders Combined catch % of total catch	6 63 tonnes 77%	10 71 tonnes 27%	13 125 tonnes 84%
> 15 tonnes	No. licence holders Combined catch % of total catch		7 150 tonnes 57%	< 5*

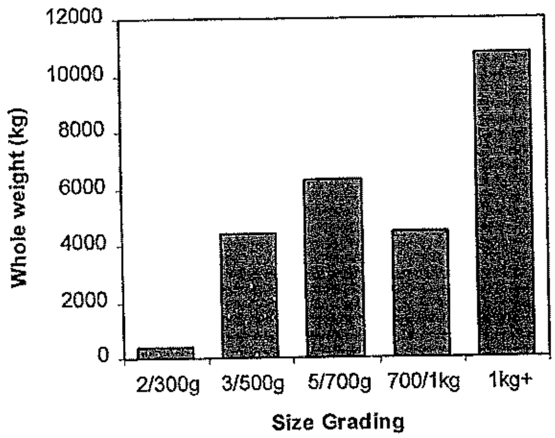
* NB: In 1998, less than 5 licence holders reported catches greater than 15 tonnes. These catches were included in the 5 – 15 tonne category for confidentiality reasons.

Figure 8. **Weekly size gradings of cuttlefish purchased from Block 21 by one processor during the 1998 fishing season.**

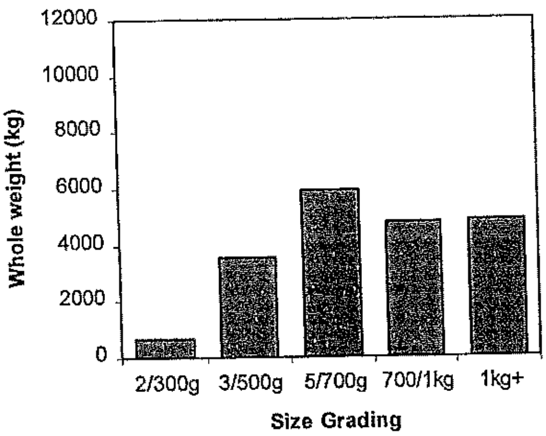
i. Week ending 10 May



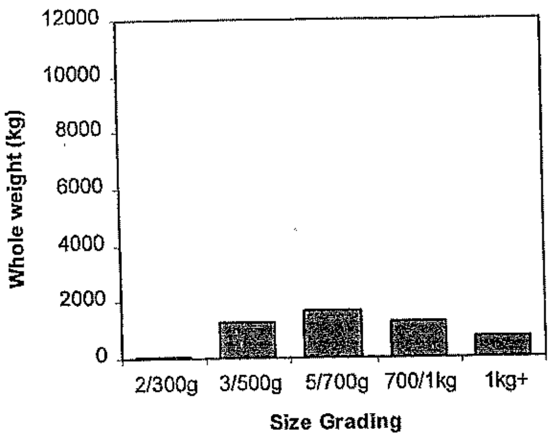
ii. Week ending 17 May



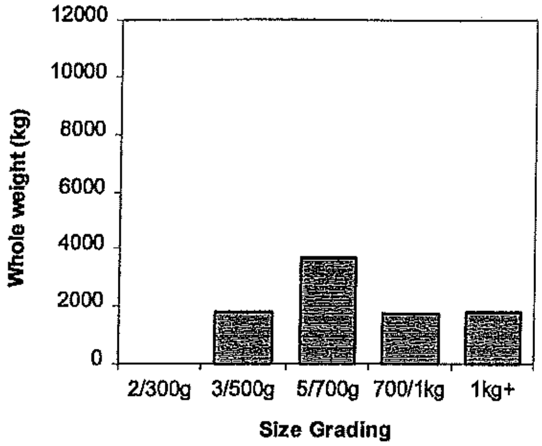
iii. Week ending 24 May



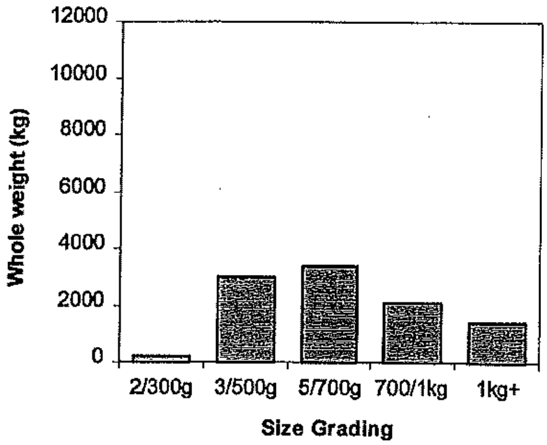
iv. Week ending 31 May



v. **Week ending 7 June**

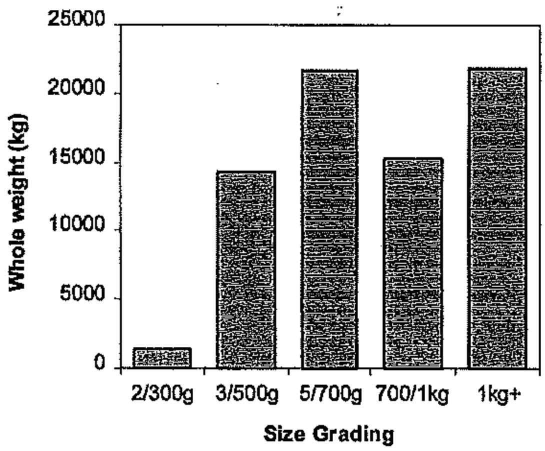


vi. **Week ending 14 June**



The overall size distribution in 1998 (Figure 9) shows a much lower relative catch of 1kg+ fish compared to 1997. This indicates less larger animals were present in the population in 1998 compared to 1997, and might reflect the removal of large animals from the population as a result of fishing activity in previous years.

Figure 9. Total gradings of cuttlefish purchased from Block 21 by one processor during the 1998 fishing season.



3.1.6. Fish processor returns

A significant discrepancy exists between reported catches from fishers' returns and from fish processors' returns detailing purchases.

Fish processor records indicate that they purchased 82 tonnes of cuttlefish from fishermen in 1998. However, commercial catch returns indicate a total catch of 149 tonnes for the State. This suggests that processors only purchased 55% of the total commercial catch and that the remaining 67 tonnes was disposed of by other means. Likewise in 1997, approximately 75-80 tonnes of the commercial catch was not accounted for by processor purchases.

Fishers' returns indicate that cuttlefish were also retained for personal use and bait, and were sold privately. Due to the structure of catch returns, it cannot be established whether these other uses equate to the discrepancy between overall catches and processor purchases.

3.2. Recreational catch and effort

No new data were obtained on recreational catch and effort for the 1998 fishing season. Based on previous recreational fishing surveys in South Australia (as discussed in more detail in the 1997 stock assessment report), recreational catch of cuttlefish is considered to be minimal in South Australian waters with most cuttlefish being taken as by-catch to the recreational squid fishery.

3.3. Other sources of fishing mortality

Cuttlefish are taken as by-catch in the Spencer Gulf and Gulf St Vincent prawn fisheries.

The amount taken by prawn trawlers is thought to be very small (Carrick pers com).

4. RESEARCH

The main fishery for cuttlefish in South Australia is based on the annual spawning aggregation of *Sepia apama* in the waters adjacent to Black Point in northern Spencer Gulf. Therefore, the majority of research undertaken on the biology of *S. apama* in South Australia during 1998 was concentrated on this spawning aggregation. Following are the results to date arising from this research.

4.1. Stock structure

The distribution of *S. apama* is reported to extend across southern Australia, from Ningaloo Reef in Western Australia to Port Jackson in New South Wales and also along the northern coast of Tasmania. The spawning aggregation at Black Point appears to be the only aggregation of its kind across the distribution of the species. Numbers increase in other coastal areas during the winter months, while spawning takes place (Gales *et al* 1993), but not to the extent that occurs in the waters adjacent to Black Point.

The average size of cuttlefish found in the Black Point area also appears to be smaller than those found elsewhere across its distribution. The maximum size recorded for a male cuttlefish at Black Point was 40cm, as opposed to the maximum size of 60cm, that is commonly recorded for other areas, eg. Jervis Bay, NSW (Watson-Russell, 1981). There are a number of possible explanations for this apparent difference in size, including differences in environmental conditions or food availability between the regions, or the removal of large animals from Black Point through fishing. Alternatively, it might also reflect genetic differences between the populations.

The behaviour patterns displayed by the cuttlefish in the Black Point area were also quite different to those observed in other areas. Elsewhere across their distribution, *S. apama* have been described by recreational divers as being solitary territorial animals, inhabiting caves and overhangs (Bavendam, 1995). Even in other regions of South Australia such as near Edithburgh in the Gulf St Vincent, male cuttlefish have been reported to occupy and guard dens (Rowlings, 1994). However, in the Black Point area, cuttlefish aggregate in large numbers and show little territorial behaviour with respect to space, but do show strong "mate-guarding" behaviour.

The above evidence suggests that the spawning aggregation occurring at Black Point each year might be a unique population that is not directly related to any other populations of *S. apama* in South Australian waters.

An allozyme electrophoresis study planned to commence in 1999, will help clarify the stock structure of *S. apama* occurring in South Australia. However, until further information is available it is prudent to manage the population at Black Point as a single stock which relies entirely on its own successful spawning events to sustain itself.

4.2. Surveys

4.2.1 Reef area estimates

In March 1998, habitat surveys were conducted in the Black Point to Point Lowly area in order to quantify the area of reef present which might be suitable for cuttlefish habitation. Underwater visual transects were run perpendicular to the shoreline, commencing at the shoreline and extending out until hard bottom reef finished and gave over to sand. All areas around Black Point and Point Lowly where reef was found to occur were surveyed using these transects.

The reef area closed to fishing at the commencement of the 1998 fishing season was estimated to be 46% of the total reef area, with 56% of the reef area still remaining open to fishing (Table 3).

Two main habitat types were identified in the area, a) an "urchin habitat", which occurred between 2-5m depth, and consisted of solid low relief reef or cracked bedrock with short algal clumps and high densities of sea urchins; and b) an "algae habitat", between 5-8m depth, consisting of tall stands of brown algae over patchy reef and sand.

Table 3. Area of reef habitat estimated to be within the closed area and area left open to fishing.

Region	Shore Length (km)	Av. Width of Habitat (m)		Area of Habitat (,000 m^2)	
		Urchin	Algae	Urchin	Algae
False Bay - Black Pt	1.010	34	5	34.1	5.3
Black Pt	1.163	48	18	55.3	20.4
3rd Dip	1.163	50	35	58.2	40.7
West of SANTOS fence	1.163	64	49	74.2	56.7
Stony Pt	0.960	80	35	76.8	33.6
SANTOS Jetty	0.560	75	35	42.0	19.6
SANTOS Tanks	0.560	123	83	68.6	46.2
Waroona Bay reef	0.110	65	55	7.2	6.1
Point Lowly	0.340	55	35	18.7	11.9
Point Lowly - Boat ramp	0.790	55	35	43.5	27.7
Fitzgerald Bay	1.010		15		15.2
BHP Wall	0.625	10		6.3	
Totals	**Open**	**431,000 m^2**	**56%**		
	Closed	**337,000 m^2**	**44%**		
	Total	**768,000 m^2**			

4.2.2 Cuttlefish density estimations

Three sites in each of the fished and closed areas were monitored throughout the spawning season (Figure 10). Two additional sites in areas where cuttlefish were previously known to occur were also monitored, one in Fitzgerald Bay that remained open to fishing and one at the BHP Pellet Plant wall at Whyalla which has always remained closed to fishing.

At each site, four 2 by 50m transects were completed in each habitat type at each sampling time. Two main habitat types – "urchin" and "algae" – were sampled at each of the three main sites within the closed and fished areas, and one different habitat type at each of the two additional sites. At the start of the season the sites were monitored every third week and then towards the end of the season about once a month.

Every cuttlefish encountered was recorded, their length estimated and their sex and behaviour noted. This provided density estimates of the number of cuttlefish per 100 square meters.

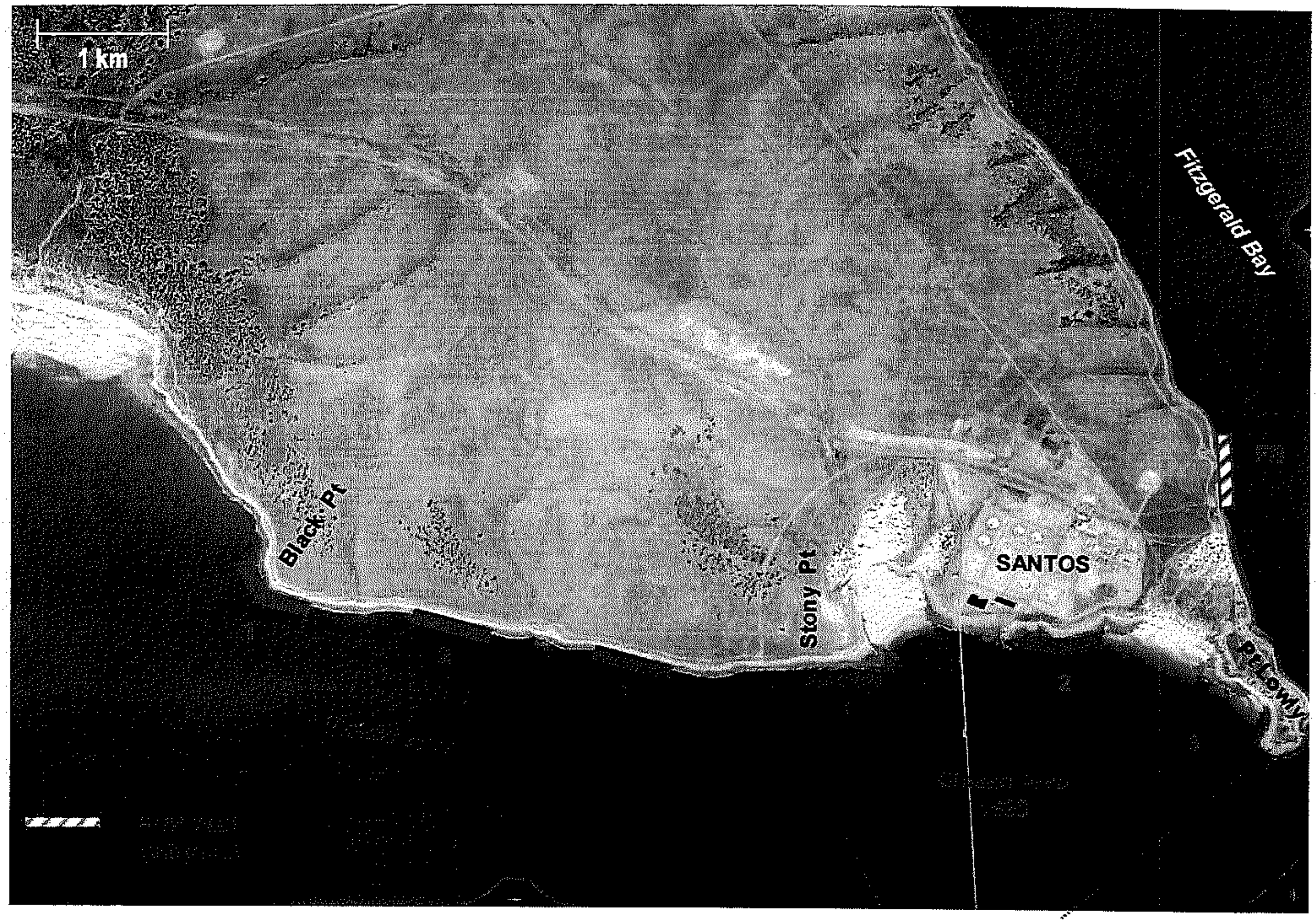


Figure 10. Location of sampling sites in the Black Point to Point Lowly area.

The average densities of cuttlefish recorded at each time monitored during the spawning season are provided in Figure 11 for the sites closed to fishing in the 1998 fishing season and Figure 12 for the sites that were subjected to fishing.

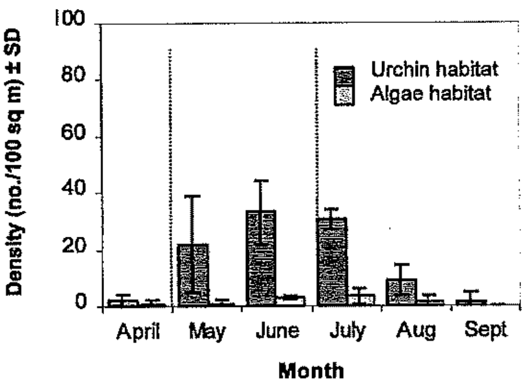
Average densities of cuttlefish varied both temporally and spatially over the sites, with some sites having consistently higher densities of cuttlefish than others.

There were virtually no cuttlefish recorded at any of the sites up until the end of April, and then in the last few days of April the cuttlefish first arrived. The fishing season commenced around the same time, indicated by the first dotted line in each graph. The second dotted line indicates when the fishing season was closed in the main fishing grounds. By the end of August, nearly all cuttlefish had vanished from all sites (either due to emigration out of the area or mortality or both).

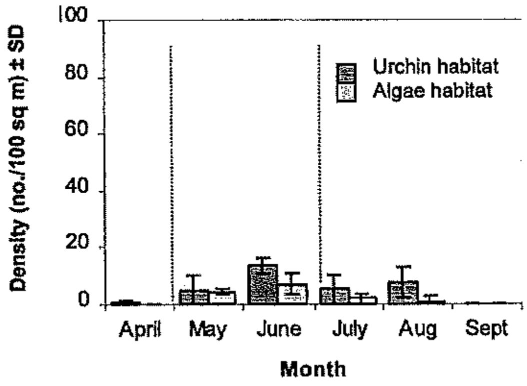
Densities also varied according to habitat type. There were consistently more cuttlefish found in the "urchin habitat", than the "algae habitat" at all sites and times monitored. The "urchin habitat" is obviously the more important in terms of cuttlefish abundance, of the two habitat types monitored.

Figure 11. Average densities of *S. apama* recorded for sites left open to fishing.

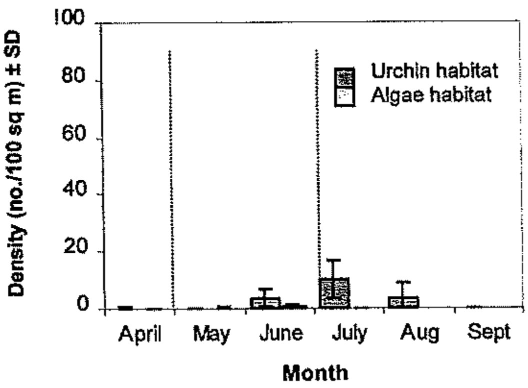
i. Site 1 - Stony Point



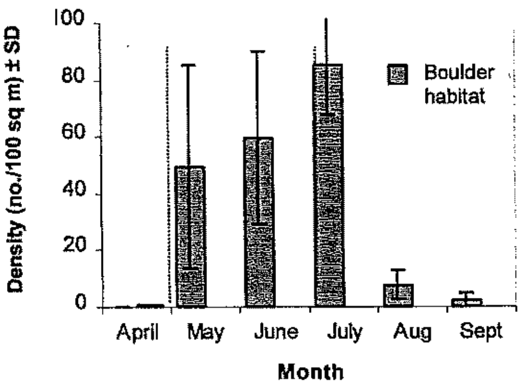
ii. Site 2 - SANTOS Tanks



iii. Site 3 - Point Lowly



iv. Additional Site - BHP Wall



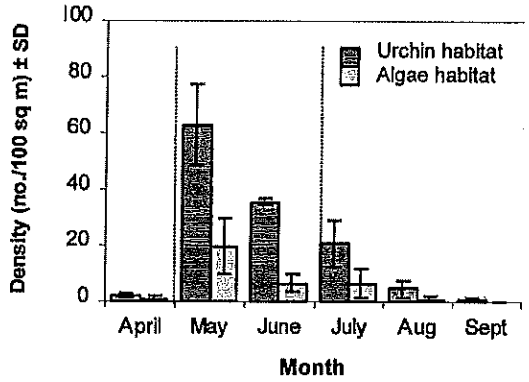
Site 1 (Stony Point, Figure 11i) was the only site in the closed area that recorded high densities. The other two sites, Site 2 (in front of the SANTOS tanks, Figure 11ii) and Site 3 (Point Lowly, Figure 11iii) recorded very low densities through out the spawning season.

Densities at Stony Point, rose gradually at the start of the season (May-June), stabilised somewhat (June-July) and then declined gradually towards the end of the season (July-Sept) (Figure 11i).

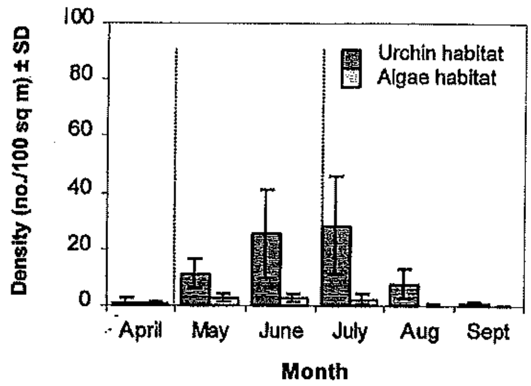
At the BHP Pellet Plant wall at Whyalla (Figure 11iv), which has always been closed to fishing, very high densities were recorded (the highest of all the sites) and they continued to rise through out the season until the end of July. However, this site covers only a very small area so although dense, it actually represents only a small amount in terms of total abundance.

Figure 12. Average densities of *S. apama* recorded from sites left open to fishing.

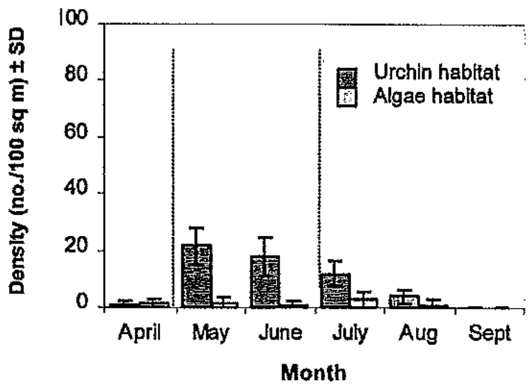
i. Site 1 - Black Point



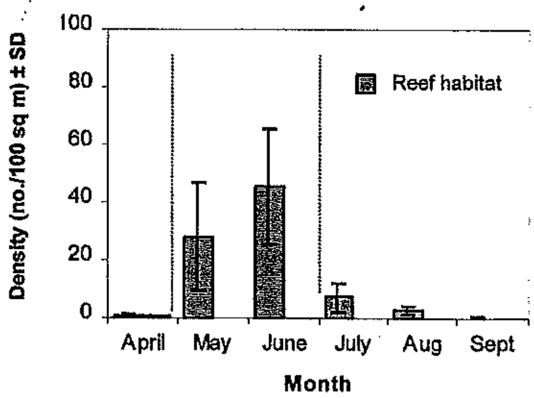
ii. Site 2 –"Third Dip"



iii. Site 3 - West of SANTOS Boundary Fence



iv. Additional Site - Fitzgerald Bay



Site 1in the fished area (Black Point, Figure 12i) consistently recorded the highest densities of any site within the area, even though it was the site subjected to the highest fishing pressure. There appears to be something unique about Black Point that attracts cuttlefish in extraordinary numbers.

Unlike the temporal trend observed in the closed area, at Black Point densities did not continue to rise after the initial rapid increase in May, instead they declined through out the remainder of the season.

A similar decline can also be seen in the densities recorded at Site 3 in the fished area (west of the SANTOS boundary fence, Figure 12iii), although, densities at this site were generally lower than those recorded at Black Point.

Surprisingly, the other fished area site, Site 2 ("Third Dip", Figure 12ii), reflects a similar temporal trend as those sites in the closed area. This might be due to the lower fishing pressure exerted at this site, compared to the other two fished sites. Even though it was in the area open to fishing, it was rarely fished.

The additional site monitored (Fitzgerald Bay, Figure 12iv) which also remained open to fishing, displays a similar increase in densities at the start of the season as was observed in the closed area. However, this site was also rarely fished, until the main fishing grounds were closed on 11 June 1998. Following the closure, Fitzgerald Bay was left open to fishing and a subsequent decrease in densities at this site was observed.

4.2.3. Abundance estimates

Abundance estimates were calculated for each site by multiplying the average density of cuttlefish recorded in the site by the corresponding reef area estimate.

Figure 13 shows the estimated total abundance of cuttlefish at Site 1 in the fished area (Black Point) through out the spawning season. The changes in abundance observed at the Black Point site, indicate that cuttlefish continue to move into the area after the initial influx of animals at the start of the season.

In the last week of April there were virtually no cuttlefish in the area, but within just five days the estimated abundance rose to around 10,000 animals. Soon after the arrival of the animals the fishing season commenced (as indicated by the first dashed line in Figure 13).

By the second week of May, the abundance was estimated to have risen to around 25,000 animals. However, this was apparently insufficient animals to sustain economically viable catch rates for the fishermen, so a 10-day voluntary closure was introduced by the fishermen on 15 May 1998 (indicated by the second dashed line in Figure 13). Within just 4 days following the introduction of the closure, the abundance of cuttlefish had risen by approximately a third to around 40,000 animals.

Fishing resumed on 25 May 1998 (indicated by the third dashed line in Figure 13), and by 1 June 1998, the total abundance of animals at the Black Point site had declined to about half that recorded in the middle of May. The abundance continued to decline throughout the remainder of the season.

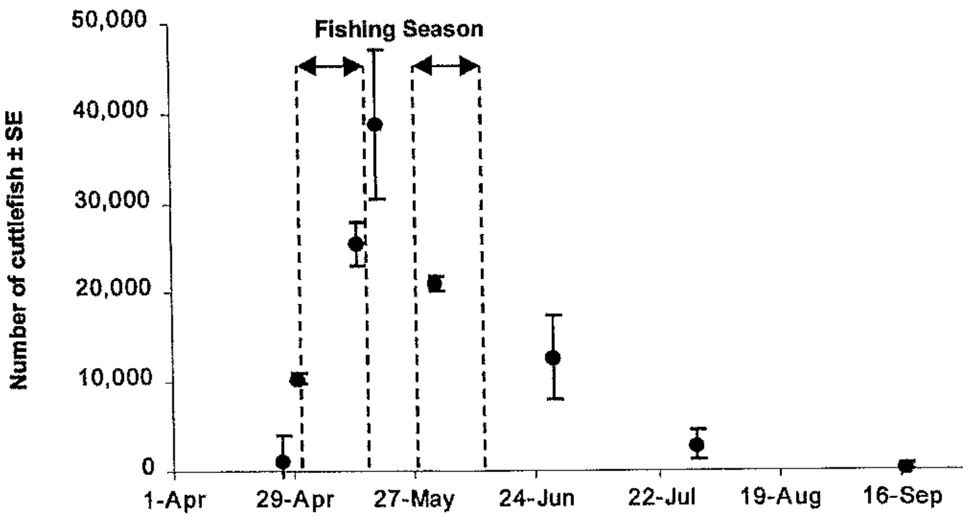


Figure 13. Total abundance estimates for the Black Point site at various times during the 1998 spawning season.

Total abundance in the fished area and the closed area were estimated by combining the abundance estimates for all fished sites and for all closed area sites respectively (Figure 14). There were a number of assumptions involved in the generation of these estimates, including the assumption that no movement from the closed area into the open area (or vice versa) occurred. This assumption will be tested during the 1999 spawning season via tagging studies. It is also assumed that cuttlefish densities in the unsampled areas adjacent to those monitored, were the same as those recorded in the sites monitored. It was not possible to monitor the densities of cuttlefish over the entire reef habitat in the area due to time and money constraints.

Numbers of cuttlefish in the closed area rose at the start of the season, levelled out somewhat and then declined towards the end of the season. Whereas, numbers in the fished area increased rapidly at the start of the season and then declined throughout the remainder of the season.

The most important point to note, is that even with the absence of fishing removing animals from the closed area, the numbers in the closed area never reached the level of those observed in the fished area.

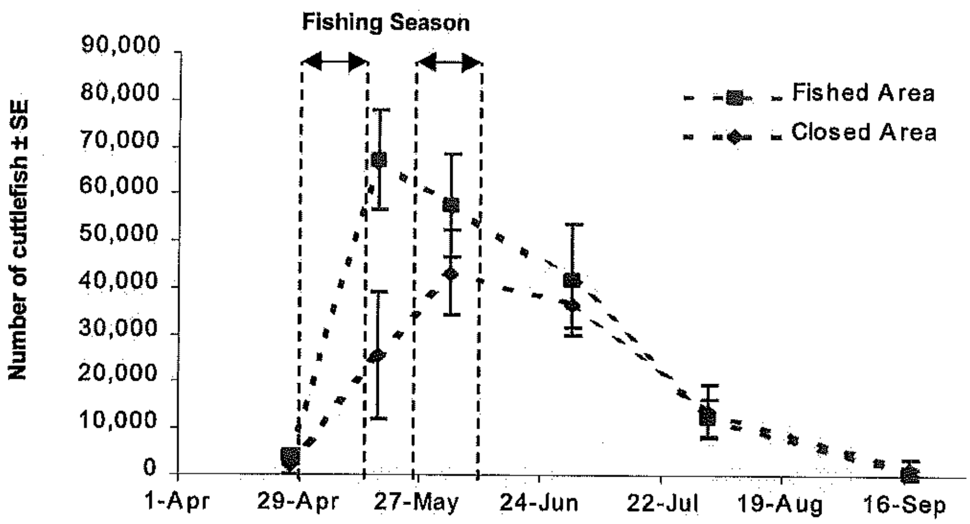


Figure 14. Total abundance estimates for the closed area and area left open to fishing.

4.3. Biomass estimates

Biomass estimates were calculated using the length estimates recorded for each cuttlefish encountered on the underwater transects. Estimated lengths were converted to weights according to the appropriate length-weight relationship (Section 4.4.4.) to obtain an average weight per transect. Biomass estimates for each site were then obtained by multiplying the average weight per transect by the corresponding reef area estimate.

The resulting total biomass estimates for the closed area and the fished area are shown in Figure 15. Similar trends can be seen in the biomass estimates for the closed area and the fished area as were seen in the total abundance estimates.

In order to take into account the biomass of cuttlefish removed from the fished area through fishing (ie. the catch), the cumulative catch was added onto the biomass estimate for the fished area (blue line in Figure 16). This provided an estimate of what the total biomass in the fished area might have been had fishing not occurred.

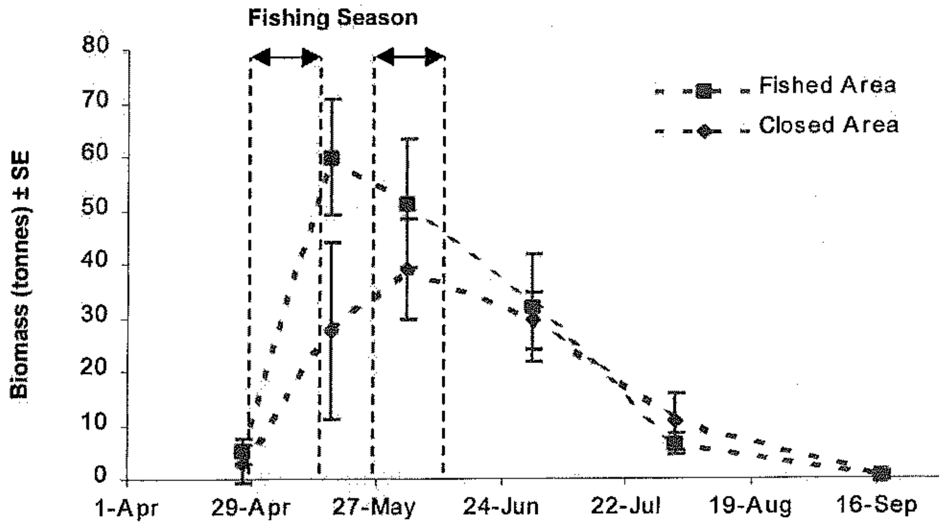


Figure 15. Total biomass estimates for the closed area and area left open to fishing.

However, the closed area biomass estimate appears to undergo a natural decline towards the end of the season, due to either emigration out of the area or mortality or both. Therefore, it is unlikely that all the animals that were removed as catch during the season, would have been there at the end of the season. So, the initial estimate of biomass in the fished area (blue line in Figure 16) was decayed towards the end of the season at the same rate of decline as displayed in the closed area biomass, to derive a more reliable estimate of biomass for the fished area (solid red line in Figure 16).

By adding the closed area biomass estimate onto the estimate of total biomass in the fished area, an estimate of total biomass in the whole Black Point to Point Lowly area was calculated (solid green line in Figure 16). For 1998, the estimated total biomass was 199 tonnes, which consisted of 89.9 ± 15.2 tonnes of surveyed biomass (closed and fished areas combined), plus 109 tonnes of catch (accumulated up until the time the closed area biomass was found to start declining).

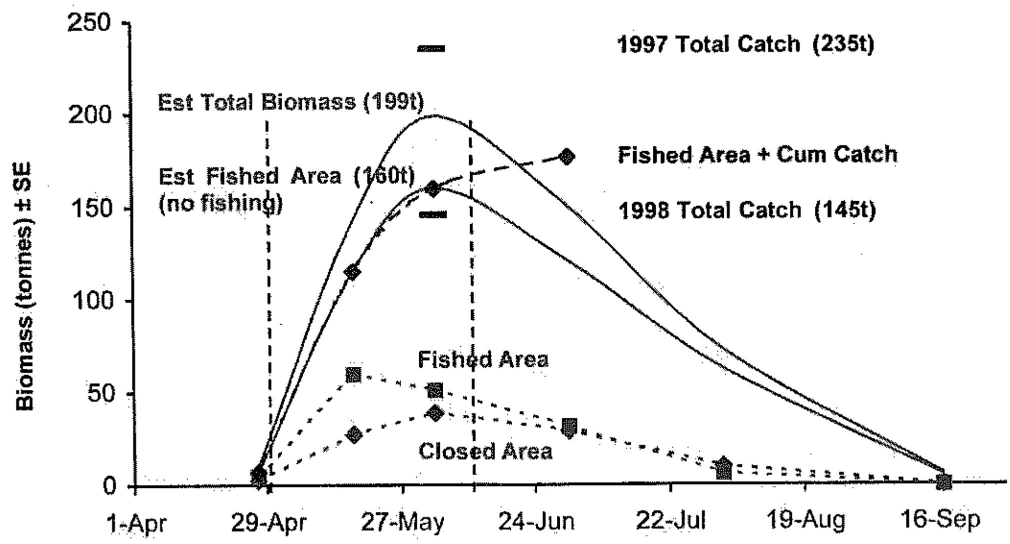


Figure 16. Total biomass estimates for the closed area, the fished area and the whole Black Point to Point Lowly area.

This estimate of total biomass involves a number of assumptions. As for the abundance estimates, it is assumed that there is no movement of animals from the closed area to the fished area (or vice versa). It is also assumed that all of the animals migrating into the Black Point to Point Lowly area are there for the duration of the spawning season and that there is not a constant turnover of animals in the area. Furthermore, it is assumed that the average weight of cuttlefish per transect in the unsampled areas adjacent to the monitored sites, were the same as those recorded in the sites. Therefore, these numbers should be used as a guide only until some of these issues can be addressed and confidence intervals for the estimates can be calculated.

The biomass estimates obtained indicate that the biomass in the closed area only accounted for around 20% of the estimated total biomass, even though the closed area accounted for 45% of the reef habitat in the region. In addition, the catch in 1998 removed approximately 70% of the total estimated biomass, even with the fishery being closed earlier than it would normally have finished.

The most important point to note though, is that the estimated total biomass in the region for 1998, was less than the total catch removed from the area in 1997. This suggests that the population level in the area is in decline.

4.4. Biological studies

4.4.1. Sex ratios

The sex ratios recorded via underwater transects at all sites through out the season were dominated by males (Table 4). Males far outnumbered females in the population and generally, only the larger males were able to secure a female. Rarely was a female ever observed on her own without a mate and strong "mate-guarding" was displayed by males who were in possession of a female.

Towards the end of the fishing season, the already unbalanced sex ratios were even further skewed towards the males, in the heavily fished sites (Table 4). This suggests that fishing may have been responsible for further reducing the proportion of females in the fished population.

Table 4. Sex ratios (M:F) of *S. apama* recorded from underwater transects at each site during the spawning season.

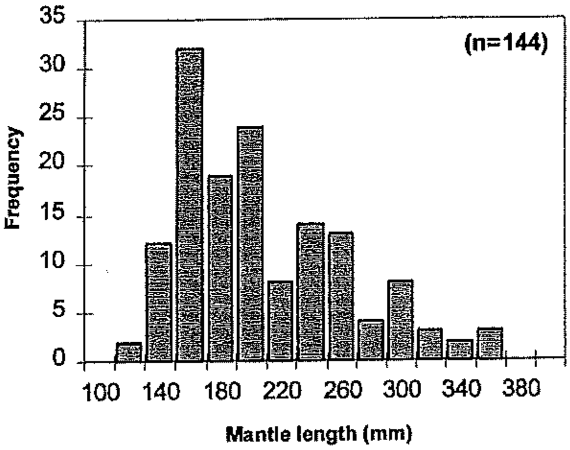
	Fished Sites				Closed Area Sites			
	Black Point	Third Dip	West SBF	Fitz Bay	Stony Point	SANTOS Tanks	Point Lowly	BHP Wall
Mid May	4 : 1	8 : 1	3 : 1	6 : 1	5 : 1	-	5 : 1	-
End May	4 : 1	2 : 1	6 : 1	5 : 1	6 : 1	4 : 1	5 : 1	12 : 1
End June	10 : 1	4 : 1	15 : 1	29 : 1	3 : 1	6 : 1	2 : 1	4 : 1

Further evidence to support this idea is displayed in the length frequency histograms recorded at each site during the underwater transects. Figure 17 shows the length frequency histograms for cuttlefish recorded at Black Point at a time early in the fishing season (Figure 17i) and later in the fishing season (Figure 17ii). It appears that the proportion of females in the population has decreased even further later in the season, but in particular the proportion of larger females.

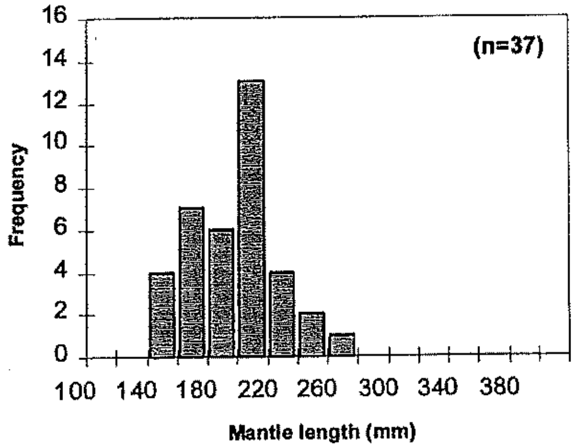
Figure 17. Length frequency histograms of *S. apama* recorded at Black Point during underwater transsects.

i. Early in the season (14 May)

a) Males

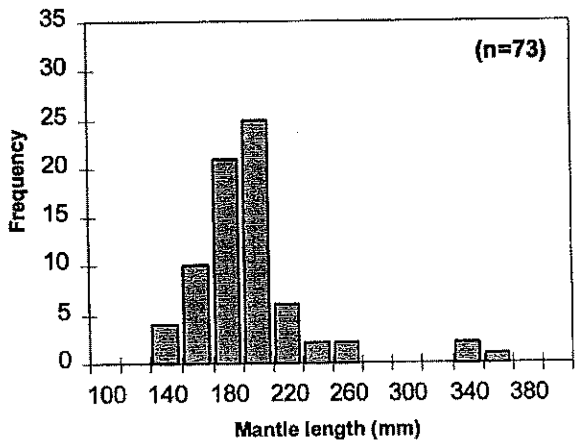


b) Females

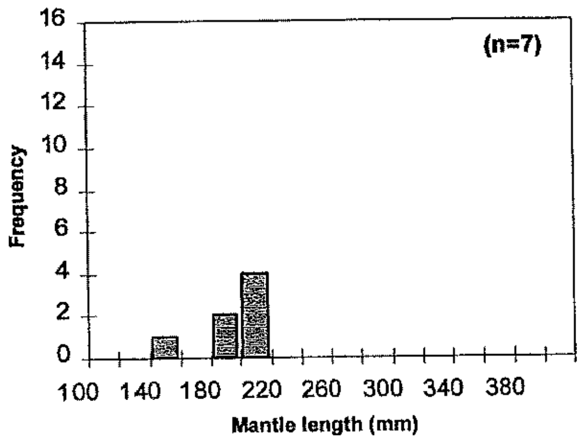


i. Late in the season (28 June)

a) Males



b) Females



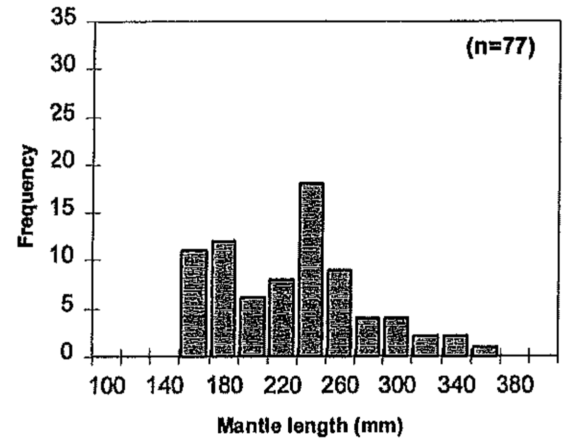
There were also a number of large size classes absent in the male frequency histogram for Black Point later in the season (Figure 17ii) when compared to the start of the season (Figure 17i). This suggests that fishing may also have been selectively removing the larger males from the population (as was also indicated in the processor size grading records, Section 3.1.6.).

In comparison, the length frequency histograms for cuttlefish recorded at Stony Point at the beginning and towards the end of the fishing season (Figures 18i and 18ii) indicate an increase, as opposed to a decrease, in the proportion of females in the population later in the season. However, there does appear to be a shift towards more smaller females. In addition, the large size classes of males are all still present towards the end of the spawning season.

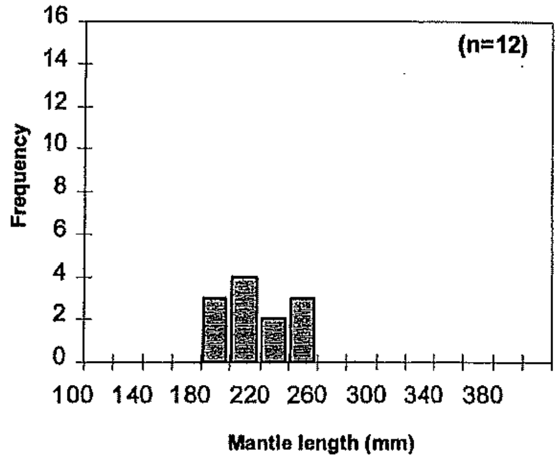
Figure 18. Length frequency histograms of *S. apama* recorded at Stony Point during underwater transects.

i. Early in the season (15 May)

a) Males

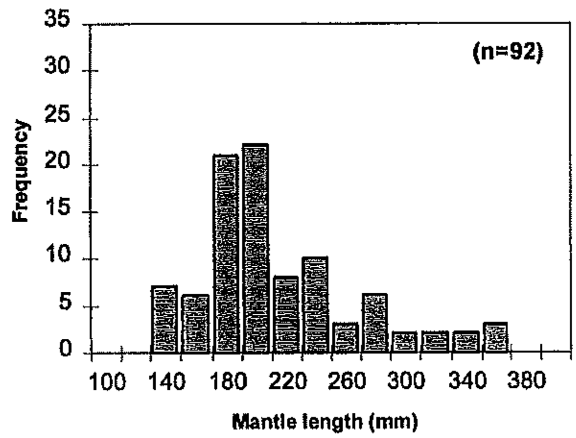


b) Females



i. Late in the season (29 June)

a) Males



b) Females

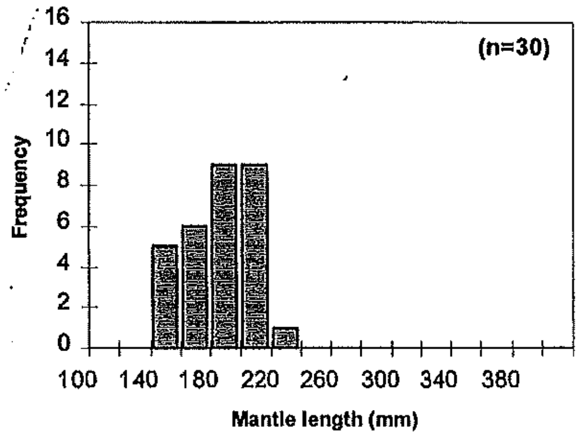
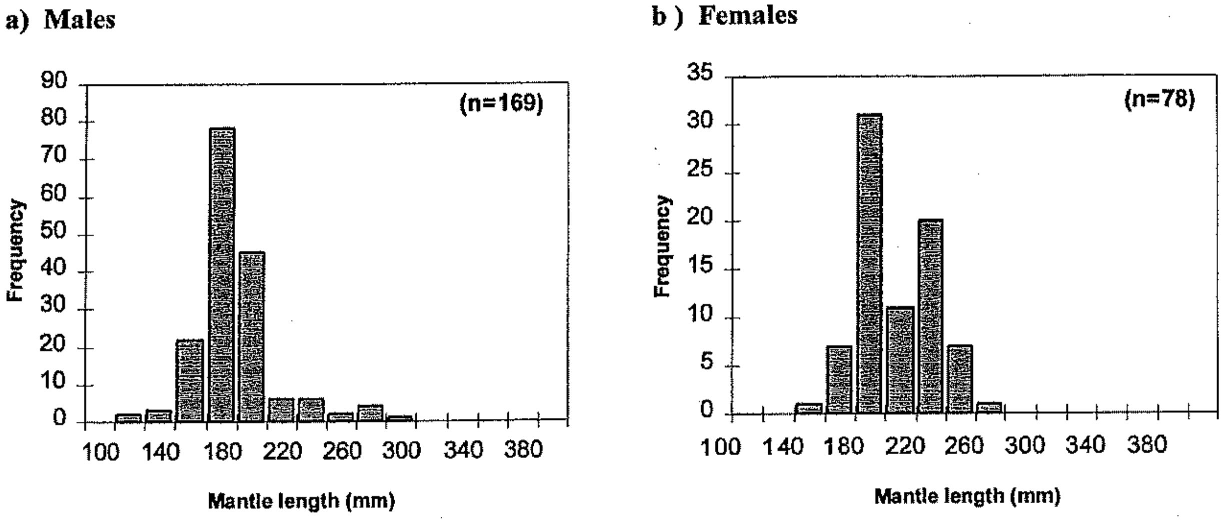


Figure 19 shows the length frequency histograms of a random sample of cuttlefish taken from the commercial catch midway through the season. It indicates that there were a larger proportion of females within the catch than was actually present in the population, suggesting that fishing may have been selective towards the taking of females.

Unfortunately, the commercial catch was only sampled at one time during the fishing season and it is not known if this is a consistent occurrence through out the season. Independent jigging at the beginning of the season suggested that this bias towards females may only be occurring later in the season and not at the beginning of the season. Further independent sampling via various means during the 1999 fishing season will hopefully resolve this issue.

However, even if females are only being removed in greater proportions later in the season, this may be having a significant impact on the number of females migrating to the area in subsequent seasons. If this were the case, the skewed sex ratios noticed at all sites in 1998, may have resulted from the removal of females via fishing in previous years.

Figure 19. Length frequency histograms of *S. apama* sampled from the commercial catch, 27 May 1998.



4.4.2. Collection of cuttlefish for dissection

A sample of around 30 cuttlefish was collected from Black Point at each time underwater surveys were conducted in the area and returned to the laboratory for dissection. Details of the dates of collection, methods used and numbers of each sex collected are given in Table 5. All cuttlefish, except for a few collected in August, were dissected fresh and used for ageing, reproductive biology and condition assessment studies in the laboratory.

Table 5. Details of cuttlefish collected from Black Point for dissection.

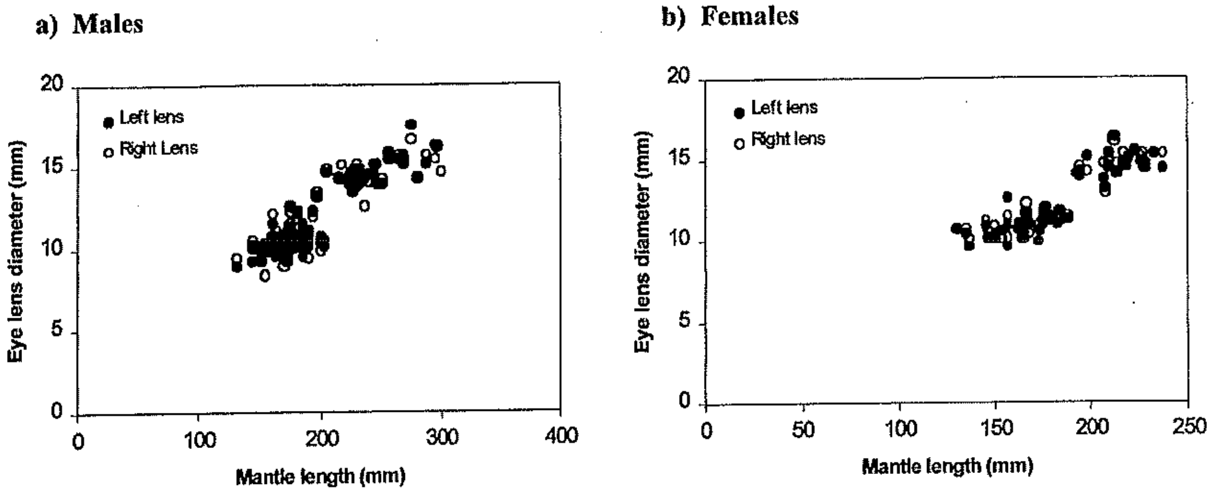
Sample Date	Collection Method*	Males	Females
30 April	Jig & Line	30	1
19 May	Jig & Line	17	13
5 June	Jig & Line / Snorkel & Net	8	22
4 July	Snorkel & Net	24	6
4 August	Snorkel & Net	6	6
4 August (frozen)	Snorkel & Net	15	4
Total		100	52

* NB: The snorkel and net collection method allowed the removal of all animals from within a given area

4.4.3. Ageing

The only ageing work completed on *S. apama* to date, used the simple method of measuring the diameter of the eye lens. Numerous studies have used eye lens diameter or dry weight as a means of assigning age to many different types of animals (eg. rabbits, antelope and squirrels). Douglas (1987), found that the average lens diameter of brown trout, *Salmo trutta*, increased with age and could be used as a simple, accurate indicator of age. The same techniques were applied to the freshly dissected eye lenses of *S. apama* sampled from Black Point through out the spawning season (Figure 20).

Figure 20. The relationship between eye lens diameter and mantle length for *S. apama*.



There appears to be two distinct groupings in the eye lens diameters of female *S. apama* collected from Black Point (Figure 20b), suggesting that there could be two age groups of females present in the spawning aggregation. One group of smaller females with mantle lengths of between 120 – 190mm and an eye lens diameter of around 10-12mm and then a group of larger females with mantle lengths between 190 – 250mm and an eye lens diameter around 12-17mm.

The males appear to have the same distinct group of smaller animals, with similar dimensions as the females, however, the larger size classes are not so clear cut (Figure 20a).

Although this method is rather crude, it gives a clear indication that there could be more than one cohort or generation present in the spawning aggregation. Therefore, the smaller animals present in the spawning aggregation in any given year, might be returning to spawn again in the following year. Many cuttlefish species are thought to be semelparous, that is spawn once and then die. However, the disparity in eye lens diameter groupings suggests that this may not necessarily be the case *for S. apama*.

Other methods of age determination (using growth rings present in the statoliths, cuttlebones and possibly beaks) are currently being investigated which will hopefully provide a more accurate indication of age in *S. apama*.

4.4.4. Length - weight relationship

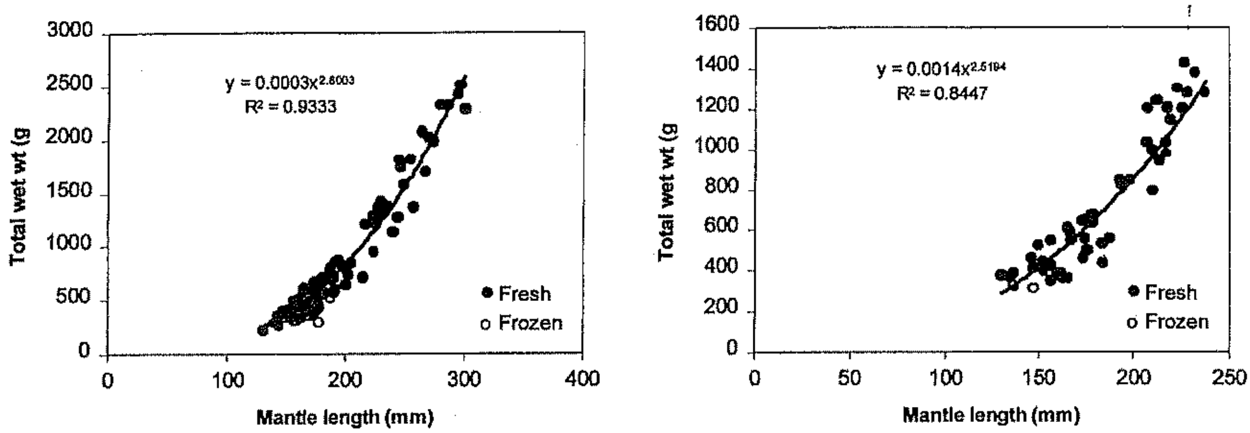
The length-weight relationships determined for male and female *S. apama* collected from Black Point through out the spawning season are given in Figure 21. The relationships obtained indicate that males increase in weight in relation to length at a faster rate than females.

The length-weight relationships determined were used to convert length estimates recorded on underwater transects into weight estimates in order to calculate the average weight of cuttlefish per transect for biomass estimations.

The relationships held true for all animals sampled as the spawning season progressed. Cuttlefish were rarely observed feeding in the spawning grounds which might suggest the weight of an individual cuttlefish may have decreased as the spawning season progressed in relation to its length (as an effect of starvation), however, there was no indication of this in the length-weight relationships obtained.

Figure 21. The relationship between total wet weight and mantle length for *S. apama*.

a) Males **b) Females**



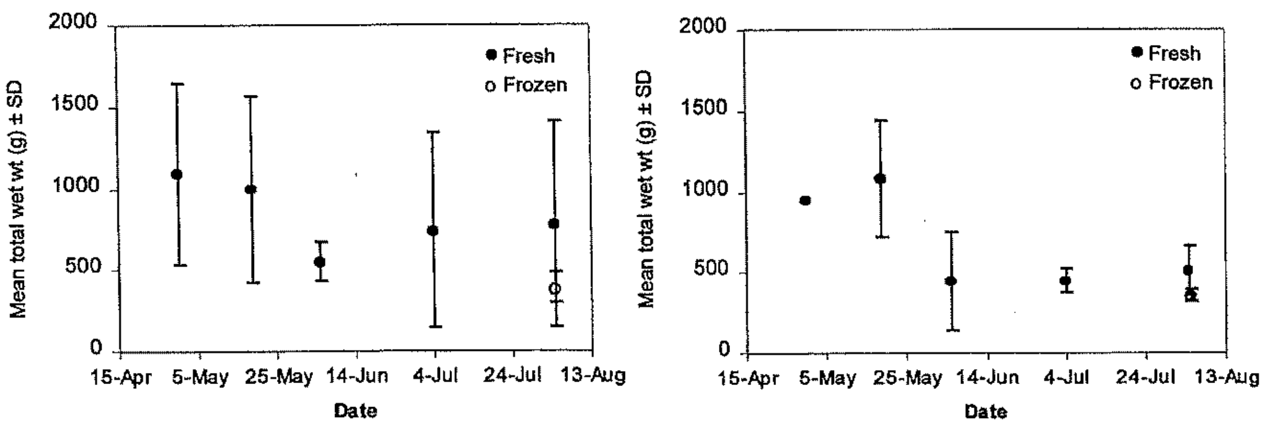
There was little change observed in the mean total wet weight of males sampled from Black Point over the duration of the spawning season (Figure 22a). However, the large standard deviations about the means suggest males of a wide range of sizes were present in all samples.

The length frequency histograms arising from the underwater visual length estimations (Figure 17) indicated a shift from larger males to smaller males as the spawning season progressed, possibly as a result of fishing. The lack of change in the male size structure during the season observed in Figure 21 may have been due to the small sample sizes involved, as very few large males (> 2kg) were found in any of the dissection samples.

The mean total wet weight of females sampled through out the spawning season (Figure 22b) show a slight decline towards the end of the season, due to the absence of any very large females in the later samples. It should be noted, however, that the sample sizes of females towards the end of the season were also relatively small, and may have failed to pick up any large females.

Figure 22. Change in mean total wet weight of *S. apama* sampled from Black Point during the spawning season.

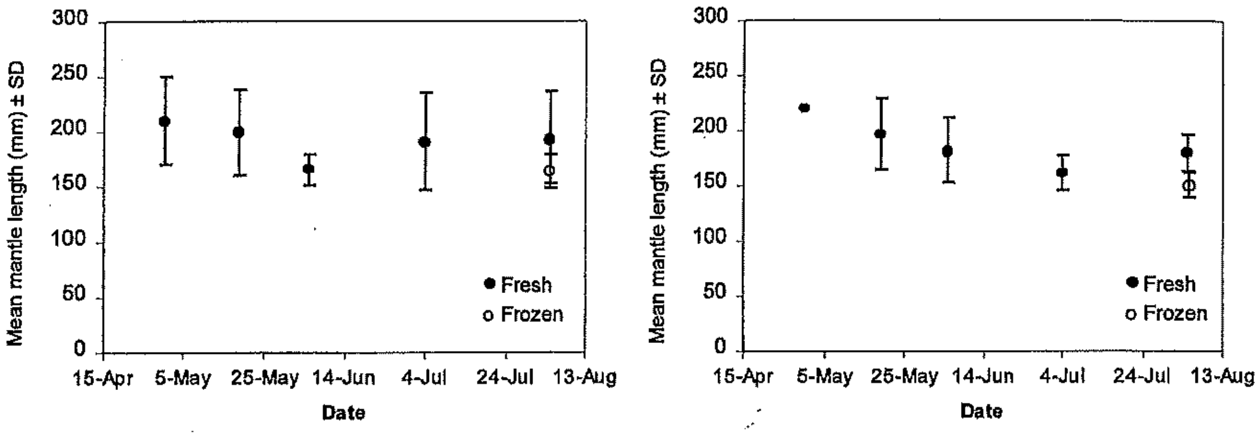
a) Males **b) Females**



Similar trends were observed in the mean dorsal mantle lengths of male and female cuttlefish collected from Black Point as the spawning season progressed (Figure 23), as you would expect given the length-weight relationships determined.

Figure 23. Change in mean dorsal mantle length of *S. apama* sampled from Black Point during the spawning season.

a) Males **b) Females**



4.4.5. Reproductive biology

Sexes in all cuttlefish species are separate. The most reliable way of distinguishing female *S. apama* from males externally is via the presence of a seminal receptacle located in the buccal membrane below the mouth of females. In addition, females have relatively shorter arms than males.

All cuttlefish collected from the Black Point area during the spawning season were sexually mature. All females had spermatophores present in their seminal receptacles, indicating that they had recently mated. Mating and egg-laying behaviours were noted on all underwater transects from April through to the middle of September. Although, there were only a few small groups of animals left in September, most animals encountered were still busy mating and laying eggs. No peak in spawning activity could be reliably detected.

The anatomy of the reproductive systems of male and female *S. apama* follow the general forms described for other *Sepia* species (Mangold 1987).

The reproductive system of female *S. apama*, consists of a single posterior ovary where eggs are produced. The ovary is connected to a single membranous oviduct (which lies dorsal to the ovary) where mature eggs are accumulated until spawning takes place. The oviduct opens into the mantle cavity through the oviducal gland, which produces a gelatinous jelly in which mature eggs are embedded before being spawned. The female also contains two large white nidamental glands (and accessory nidamental glands – the function of which is unknown) which produce secretions of gelatinous tissue used to coat the outside of embedded eggs in a protective casing as they are laid.

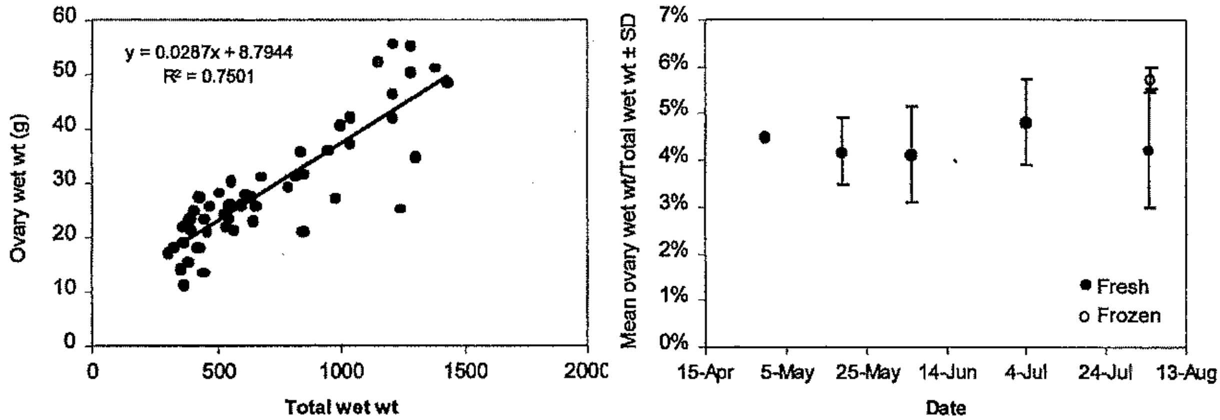
The reproductive system of male *S. apama*, consists of a single posterior testis, which produces sperm. The testis is connected by the vas deferens (sperm duct) to the spermatophoric complex (consisting of spermatophoric duct, spermatophoric organ, spermatophoric sac and penis). The spermatophoric duct directs sperm into the spermatophoric organ where is it packed into spermatophores (long thin packets of sperm accompanied by an ejaculatory apparatus) which are then stored in the spermatophoric sac until copulation occurs.

The way in which the relative weights of these various components of the reproductive system varied in relation to body size and the changes in the relative weights of each organ over the duration of the spawning season are represented in Figures 24 to 28. It might be expected, that as the spawning season progresses and animals become "spent", a decline in the relative weights of the reproductive organs would be observed and hence provide an indication as to when the peak of the spawning season had passed.

The size of the ovary showed a fairly consistent linear relationship with increasing total wet weight, such that larger females tend to possess larger ovaries (Figure 24). This suggests that larger females may have a greater reproductive output than smaller females.

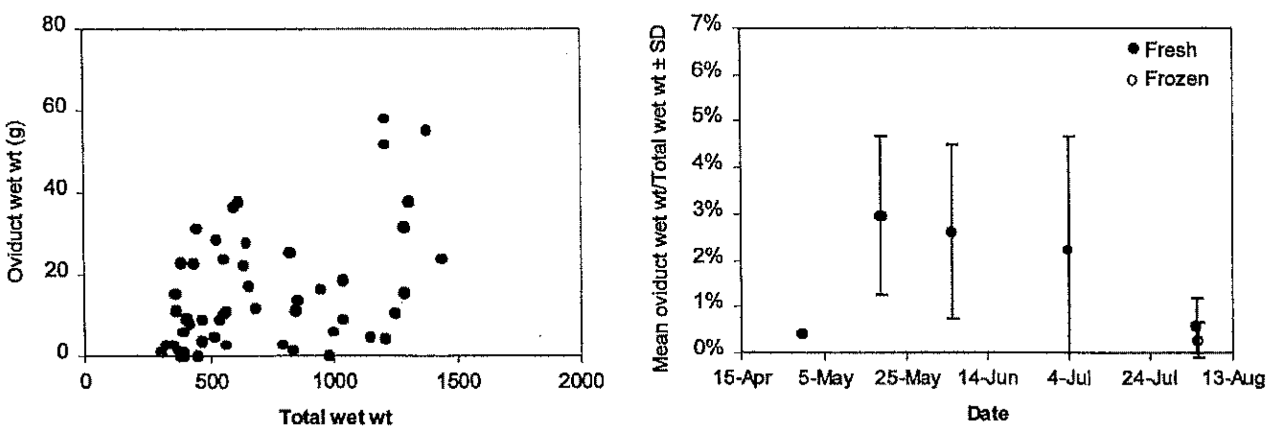
There was no decline in the ovary wet weight to total wet weight index observed in females collected from Black Point towards the end of the season.

Figure 24. The relationship between ovary wet weight and total wet weight, and the change in the ratio during the spawning season.



Oviduct wet weight varied considerably, displaying no clear relationship with total wet weight (Figure 25). This is probably a reflection on the different stages of egg laying that each female might have been at when collected. As eggs are laid, they are removed from the oviduct and are not immediately replaced. Therefore, a female collected towards the end of laying a batch of eggs will have very few eggs remaining in her oviduct. Interestingly though, all of the females collected at the beginning of August had very few mature eggs remaining in their oviducts (Figure 25).

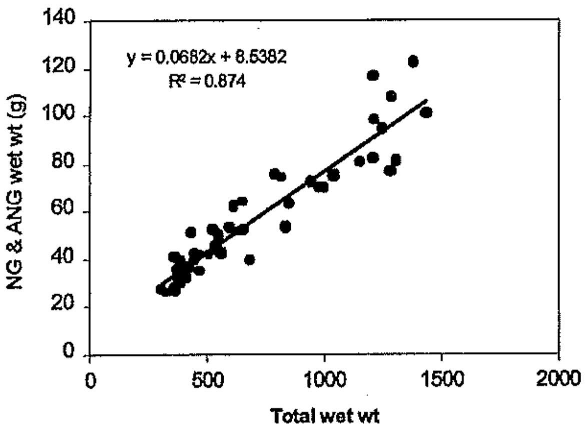
Figure 25. The relationship between oviduct wet weight and total wet weight, and the change in the ratio during the spawning season.

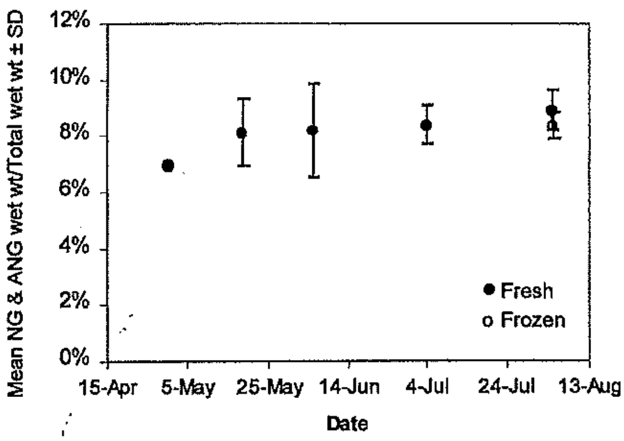


The number of mature eggs found in the oviduct of females collected from Black Point varied from 0 to 132. However, some females that were maintained in aquaria for the duration of the 1998 spawning season, who mated but never laid eggs (due to the absence of suitable spawning substrate), died with between 270 to 470 mature eggs within their oviduct.

Nidamental gland (NG) wet weight and accessory NG wet weight showed a linear relationship with total wet weight (Figure 26), and no decline in the mean relative weight towards the end of the spawning season was detected.

Figure 26. The relationship between nidimental gland (NG) and accessory NG wet weight and total wet weight, and the change in the ratio during the spawning season.

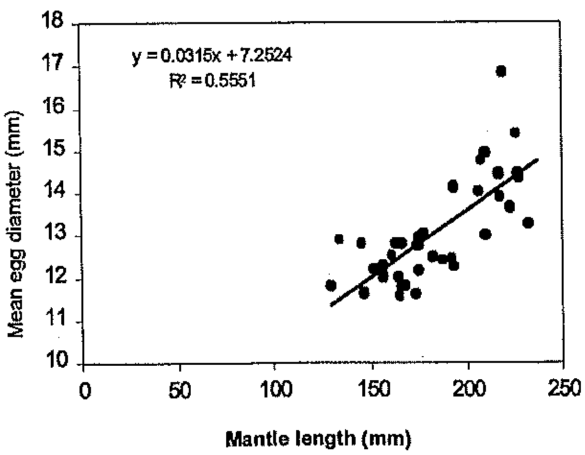


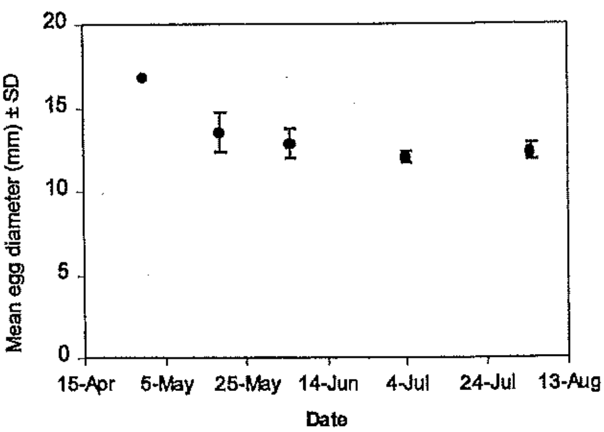


Although, not a strong relationship, the mean egg diameter of mature eggs held within the oviduct of females tended to increase with increasing mantle length (Figure 27), which implies that larger females produce larger eggs.

There appears to be a slight decline in the mean egg diameter found within females towards the end of the spawning season, as a result of the generally smaller size of the females collected at those times. Therefore, if larger females are removed due to fishing as the season progresses (as has already been suggested in Section 4.4.1.) smaller eggs may be laid in greater proportions towards the end of the season. It is not known if the original size of the egg laid has any bearing on the ultimate survival of the hatchling.

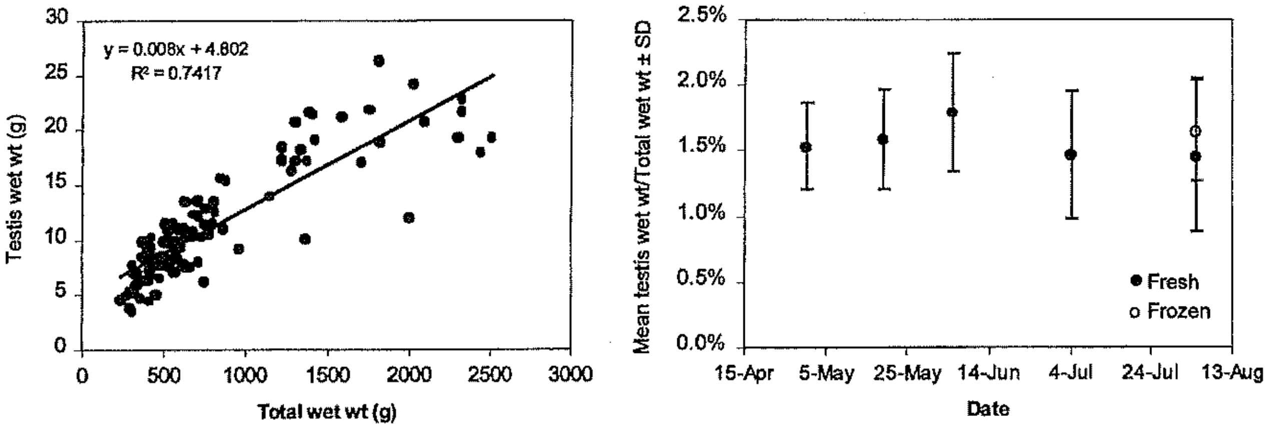
Figure 27. The relationship between mean oviduct egg diameter and mantle length, and the change in the mean egg diameter during the spawning season.





Testis wet weight displayed a fairly consistent linear relationship with body weight (Figure 28), and no decline in relative testis weight could be detected over the duration of the spawning season.

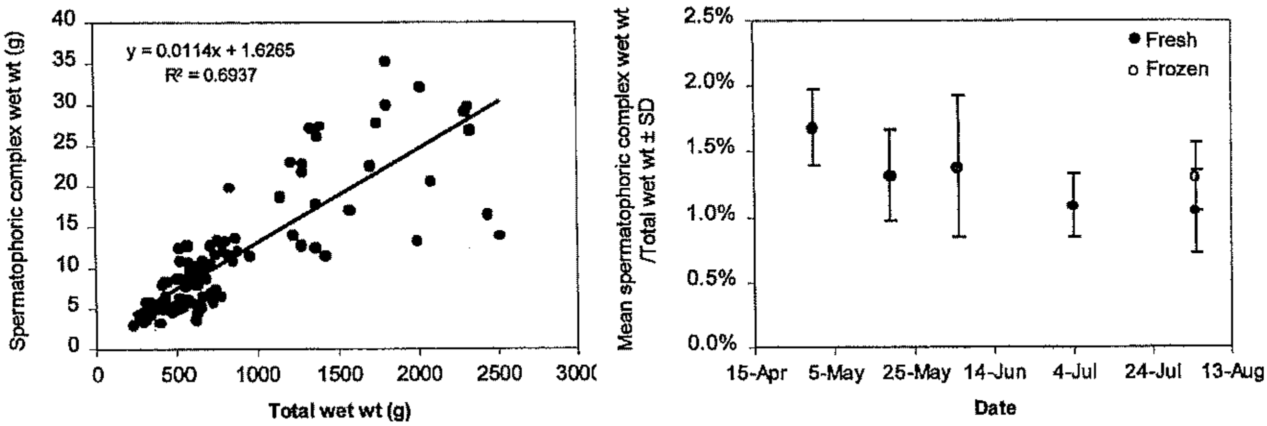
Figure 28. The relationship between testis wet weight and total wet weight, and the change in the ratio during the spawning season.



Similar to oviduct wet weights in females, the spermatophoric complex wet weight did not show a very clear cut relationship with increasing body weight (Figure 29). But like the oviduct, the spermatophoric complex is a storage organ for spermatophores ready to be used in copulation. If an animal is collected immediately after mating, one might expect the weight of the complex to be less than if the animal was about to mate.

There was a slight decline in the relative weight of the complex to total wet weight over the course of the season.

Figure 29. The relationship between spermatophoric complex wet weight and total wet weight, and the change in the ratio during the spawning season.



The mean total weight of reproductive tissue in females varied from between 12 to 15.5% of total body weight. This figure was much lower in males, with 2.4 to 3.2% of total body weight consisted of reproductive tissue. This suggests females are investing more of their energetic balance into gametic growth.

However, these figures were not high in comparison to other semelparous cephalopods, who invest greater proportions of their reserves into the production of reproductive tissue (Cortez *et al* 1995).

Preliminary observations on the size frequency of eggs within the ovaries of *S. apama* indicate the presence of eggs covering a range of developmental stages. This suggests that females may spawn more than one batch of eggs in a season, and may do so over an extended period of time (perhaps the entire spawning season). It is not yet known how many of these eggs may become mature during the spawning season and over what time period an individual female may keep spawning. Eggs of a wide variety of sizes have also been observed in the ovaries of a number of other *Sepia* species including *S. officinalis*, *S. pharaonis* and *S. dollfusi* (Gabr et al 1998), indicating an intermittent or chronic spawning strategy in those species as well.

Boletzky (1987) observed a prolonged intermittent or chronic spawning in *S. officinalis* held in aquaria. He found that the females could lay considerably greater numbers of eggs than counts of mature ovarian eggs would suggest, provided that the female survived long enough to allow full maturation of all ova that were immature in her ovaries at the start of spawning. All females spawned in his experiments eventually died, with some immature ova still in their ovaries. Similar spawning experiments undertaken on *S. apama* during the 1998 spawning season failed to produce any spawned eggs, however, the females died with very large numbers of mature eggs in their oviducts (much higher numbers that any females collected from the field).

4.4.6. Condition assessment

Most cephalopod species are thought to be semelparous (reproduce once and then die). Semelparous species commonly undergo a decline in condition during or following exhaustive spawning which ultimately results in the death of the animal (Mangold 1987).

Final sexual maturation has been demonstrated in a number of species to be reached at the expense of body muscles and the digestive gland, with a drain of resources from somatic to reproductive tissues (Cortez *et al* 1995). Furthermore, food ingestion generally decreases during and immediately following spawning, such that the energy requirements during the final period of the animals life cycle need to be met by an alternative source (Castro 1992).

The mantle of cephalopods consists primarily of muscular tissue, with proteins making up the principal component. Therefore, under conditions such as starvation or reproductive growth, the mantle proteins are likely to be utilised as an energy source (Castro *et al* 1992).

The digestive gland of cephalopods is generally considered to be a "storage organ" containing significant amounts of lipid (Castro *et al* 1992). Castro *et al* (1992) found a noticeable difference in the size of the digestive gland with respect to body size of *S. officinalis* as a result of starvation.

Therefore, the mantle wet weight and thickness, and digestive gland wet weight were monitored in animals collected from the Black Point spawning grounds in order to determine if a decline in condition was occurring in *S. apama* during the spawning season, which might indicate senescence and a semelparous reproductive strategy.

A very strong linear relationship was found between mantle wet weight and total wet weight in both male and female *S. apama* (Figure 30). There was very little variation away from this relationship and no obvious decline in the mean mantle wet weight to body wet weight ratio towards the end of the season in either sex (Figure 31).

Mantle thickness showed greater variation with respect to total wet weight (Figure 32) than the mantle wet weight did, however, there was only a minor decline in the mantle thickness to mantle length ratio towards the end of the spawning season (Figure 33).

Digestive gland wet weight also displayed a linear relationship with total wet weight in both males and females (Figure 34) and there was no indication of a decline in the digestive gland wet weight to total wet weight ratio towards the end of the season (Figure 35).

Figure 30. The relationship between mantle wet weight and total wet weight for *S. apama*.

a) Males **b) Females**

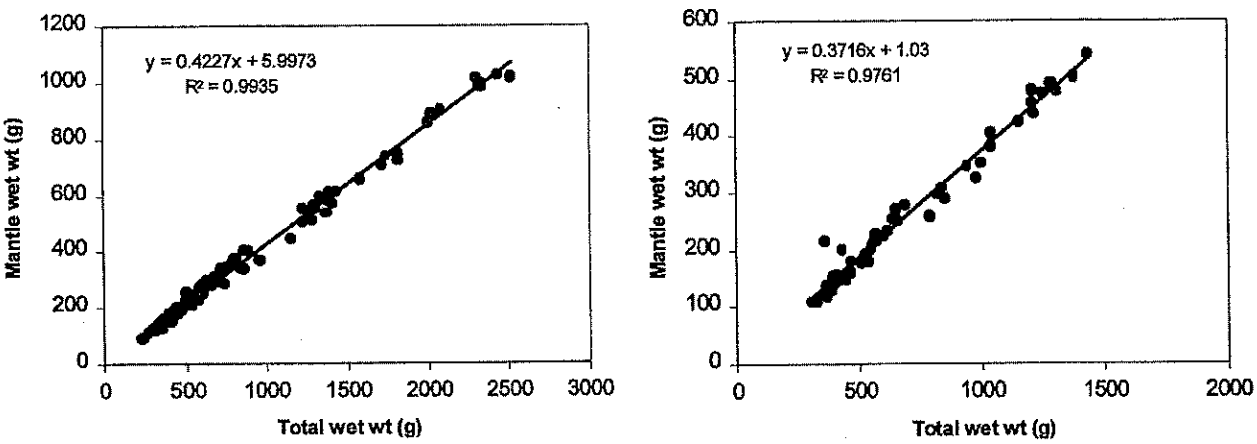


Figure 31. The change in the mean mantle wet weight to total wet weight ratio during the spawning season.

a) Males **b) Females**

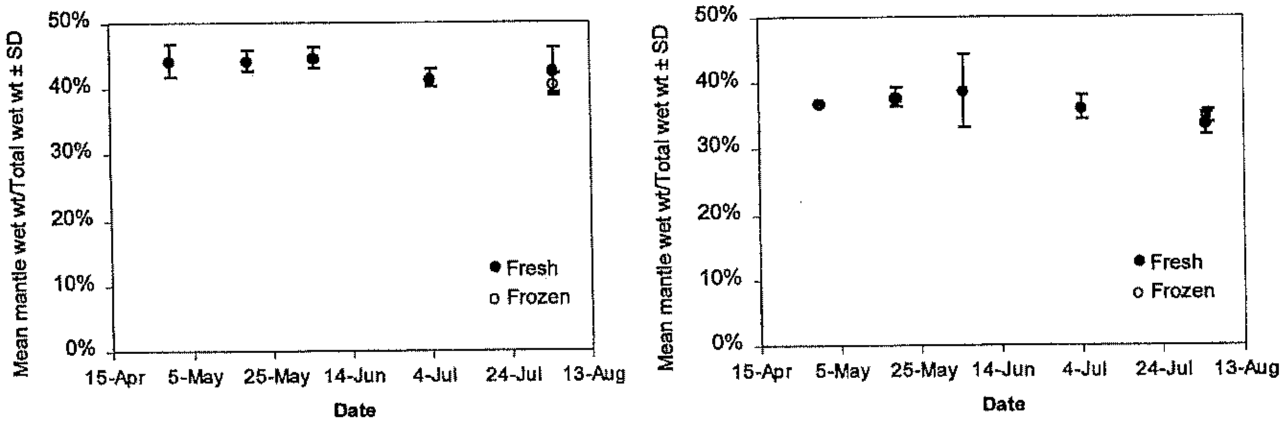


Figure 32. The relationship between mantle thickness and mantle length for *S. apama*.

a) Males b) Females

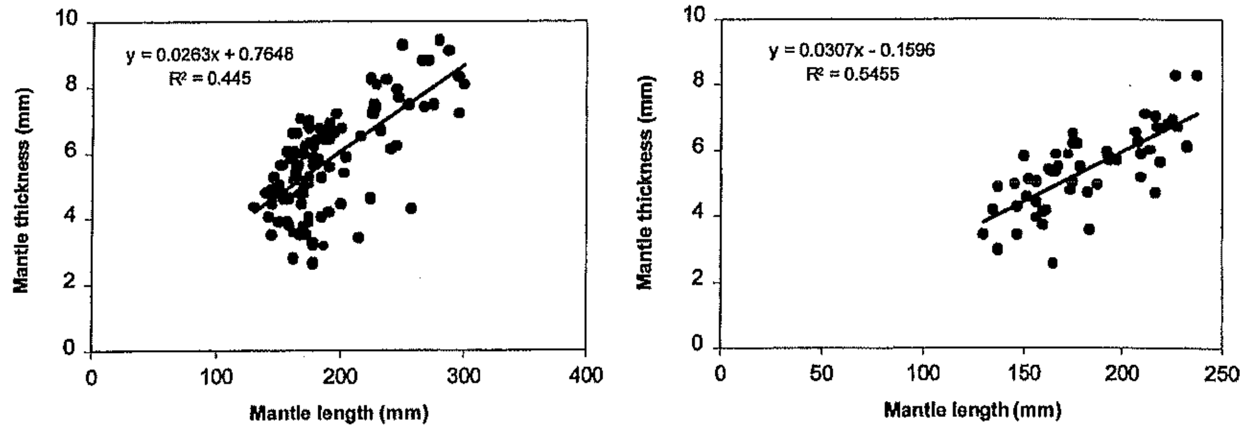


Figure 33. The change in mean mantle thickness to mantle length ratio during the spawning season.

a) Males b) Females

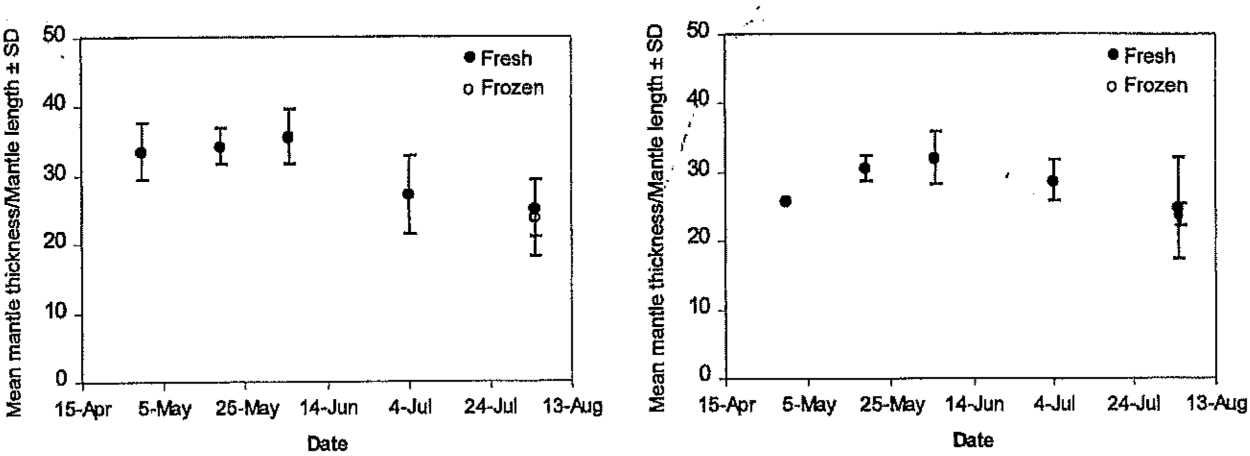


Figure 34. The relationship between digestive gland wet weight and total wet weight for *S. apama*.

a) Males b) Females

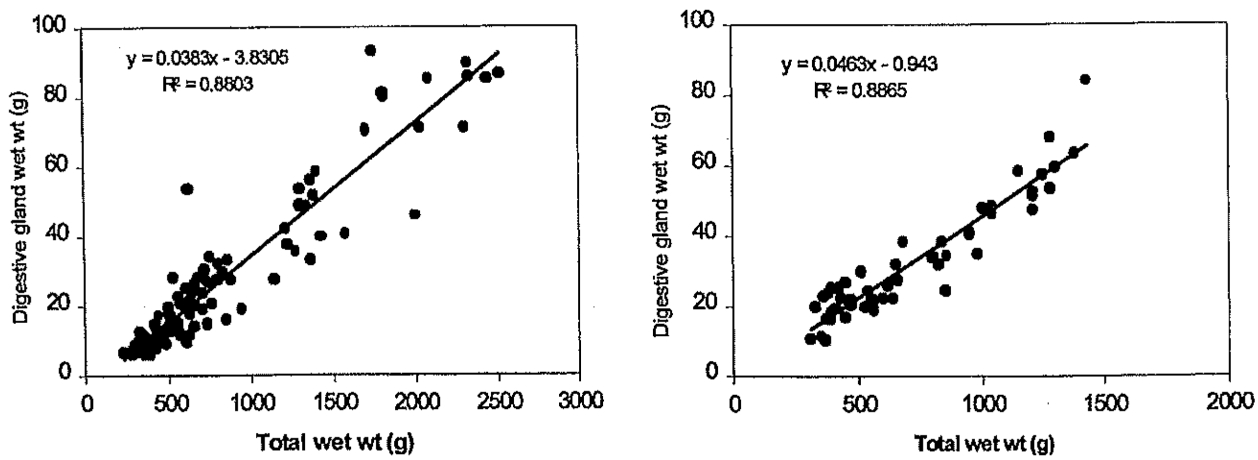
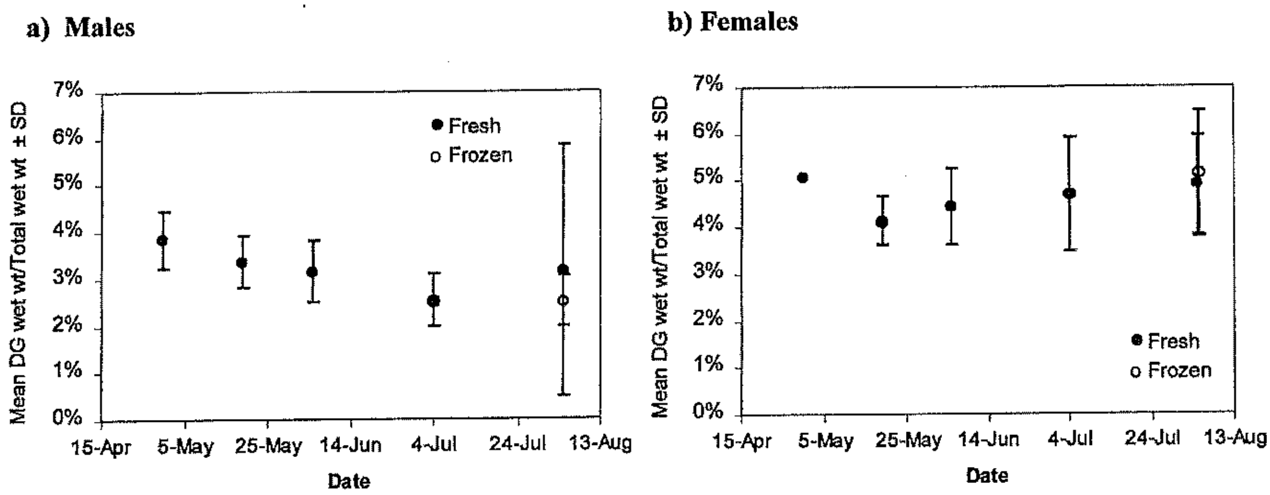


Figure 35. The change in the mean digestive gland wet weight to total wet weight ratio during the spawning season.



Therefore, no obvious decline in condition could be found in the condition indices assessed as the spawning season progressed. This suggests that animals within the spawning grounds were not loosing condition towards the end of the spawning season and may therefore not be dieing following spawning. This was a surprising result given the lack of obvious food in the spawning grounds and complete absence of any feeding observations. In addition, a small number of moribund animals were observed on the underwater transects towards the end of the season.

It is possible, however, that spent moribund animals were migrating out of the area directly following spawning, and dieing elsewhere. This has been observed and postulated for a number of other *Sepia* species (Gabr *et al* 1998). Alternatively, the animals arriving into the spawning grounds at the start of the spawning season may have already undergone a significant decline in condition while sexually maturing elsewhere, and any subsequent declines in condition may have been negligible in comparison.

However, the possibility that the animals spawning one year are living through to spawn again in the following year cannot be ruled out at this stage and should be taken into account in any management decisions being made.

4.4.7. Egg development

The time taken for cuttlefish eggs to develop was largely dependent upon temperature.

S. apama eggs held at 20°C in a constant temperature room took only 1½ months to develop through to hatching. Thirty eggs hatched over a time period of 20 days once hatching had commenced. Hatching was observed to take place in response to a disturbance, for example movement during a water exchange.

Eggs held at 15°C, first hatched after 2½ months, while those held at 10°C have yet to hatch after 6 months (though they appear to be still alive and developing very slowly).

Therefore, those eggs laid earliest in the season take the longest to develop, as their development takes place during the coldest winter months. Water temperatures in the Black Point area can reach as low as 10°C during June and July (Figure 36). Eggs laid in May started hatching in the field around the middle of September.

Those eggs laid towards the end of the season develop faster due to the increasing water temperatures present at that time of the year (ie. September to November, see figure 36). Most eggs laid towards the end of the season had hatched by the end of October.

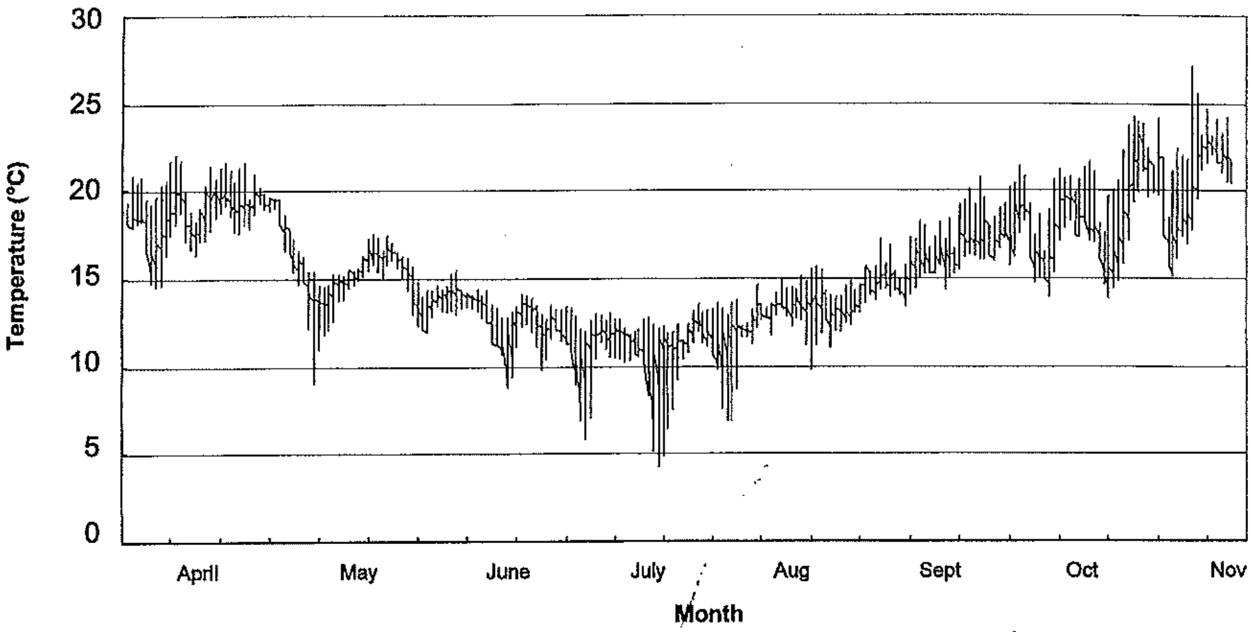


Figure 36. Raw sea temperature data collected via submersible data logger in depths < 3m at Jarrold Point between 3 April and 13 Nov 1998.
(Data from Stephanie Seddon, University of Adelaide and SARDI Aquatic Sciences).

4.4.8. Predation on eggs and juveniles

Observations on eggs in the field, strongly suggest that sea urchins in the area may be predating upon the developing eggs. Urchins were often found underneath rocks surrounded by numerous stumps of eggs and a number were caught with partially consumed eggs within their mouthparts. There are very high densities of urchins in the Black Point area, such that if they were eating the eggs they may be having a large impact on the number of eggs that actually survive through to hatching.

Hatchlings were also noticed to be predated upon by small fish as soon as they emerged from their protective casings.

5. MANAGEMENT IMPLICATIONS

5.1. Basis for recommendations

The management implications of this report are based on the following key findings (as they are currently understood).

That:

1. estimated spawning biomass has declined significantly even when compared with the previous years reported catch (from more than 260 tonnes reported as catch in 1997 to approximately 199 tonnes estimated as total biomass in 1998)

2. immigration into the spawning area begins in late April and continues for at least 4 weeks (but may continue longer)

3. spawning appears to take place from late April through to August with no peak in activity yet determined

4. individual females probably spawn more than one batch of eggs per season and possibly over an extended period of time

5. no loss of condition (indicative of senescence) could be detected in animals towards the end of the spawning season and therefore animals may be returning in subsequent years

6. more than one age class in both sexes may be present in the spawning aggregation

7. the closed area initially used in 1998 protected about 45% of the reef area but only 20% of the observed biomass (bearing in mind movement between the open and closed areas is not yet understood)

8. the fishery is capable of rapidly depleting the available biomass, even with few operators present

9. the catch is initially biased towards large animals (probably through cuttlefish behaviour rather than fisher behaviour)

10. the catch is biased towards females resulting in a highly unbalanced sex ratio in the fished population.

5.2. Objectives

Annual cephalopod species have been managed on the basis of allowing 40% escapement (Rosenberg *et al* 1990; Beddington *et al* 1990). In these cases, the biology of the species has been well understood and the fishery established for some years. The biology of *S. apama* is not yet well understood, the population appears to be in decline and the fishery is dynamic (in terms of operator numbers and effort).

A number of specific objectives for this fishery are suggested:

1. provide protection for the spawning biomass to allow rebuilding of the stock

2. provide protection for animals as they arrive at the spawning site and initiate spawning activity (particularly for larger females)

3. provide protection for animals later in the season to ensure sufficient escapement for future years

5.3. *Recommendations*

It is recommended that whatever management action is taken in 1999, a conservative management strategy be formulated which recognises the vulnerability of this population to intensive fishing effort. Successful stock rebuilding will exacerbate current interest in the fishery, particularly if better marketing strategies can be developed.

To this effect it is recommended that:

- in the event that the fishery in the Black Point to Point Lowly region remains open to the taking of cuttlefish during the 1999 spawning season, a management strategy be adopted to allow for at least 70% escapement in 1999 to facilitate stock rebuilding

and

- consideration be given to complete protection should pre-fishing biomass estimates in 1999 show evidence of further population decline.

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Cuttlefish (*Sepia apama*)

Karina C Hall

University of Adelaide & SARDI Aquatic Sciences

November 1999

Fishery Assessment Report to PIRSA for the Marine Scalefish Fishery Management Committee

South Australian Fisheries Assessment Series 99/09

Cuttlefish (*Sepia apama*)

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Cuttlefish (*Sepia apama*)

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South Australian Fisheries Assessment Series 99/09

Cuttlefish (*Sepia apama*)

ERRATA in 1999 Stock Assessment Report

Page 4

In table 3c, the data for 1997 and 1999 were reversed by accident (however, the text referred to the table as if it was correct). The corrected table is provided below.

Table 3c. Resource users – Recreational diving and tourism sector.

Year		Number of Visitors	Number of Dives	Value *
1997	- Non-local visitors - Local			$8,000 $10,000
1998	- Non-local visitors - Local - Film crews	112 3		$12,000 $6,000 $18,000
1999	- Non-local visitors (directly as result of cuttlefish) - Local - Film crews (expenditure)	420 2	1260 900	$55,000 $12,000 $36,000

* Value estimates from Tony Bramley, Whyalla Diving Services.

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In figure 8b), the change in abundance of cuttlefish in the Stony Pt area was erroneously displaced to the right by one month, suggesting a later season in that area. In addition, both figures 8a) and b) showed incorrectly calculated SE error bars. The corrected figures are provided below.

a) 1998 *b) 1999*

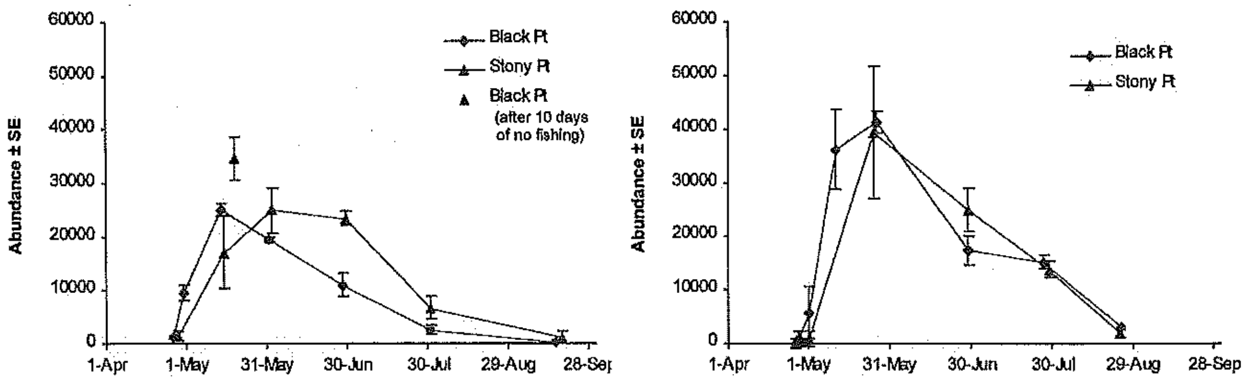

Figure 8. Total abundance estimates for the two main sites at various times during the 1998 and 1999 spawning seasons.

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Acknowledgments

The research findings presented in this report were funded by an Australian Postgraduate Award scholarship through the University of Adelaide in collaboration with SARDI Aquatic Sciences and a research grant from the Fisheries Research and Development Corporation.

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Catch and effort data for the fishery were supplied by the commercial marine scalefish licence holders through the SARDI Aquatic Sciences Statistics Department.

Summer cuttlefish samples were obtained with assistance from the Spencer Gulf prawn trawl fleet and Tony Woods of Whyalla.

1. SUMMARY AND RECOMMENDATIONS

1.1. Overview

The main objective of this third stock assessment report for cuttlefish (*Sepia apama*) in South Australia is to report on the biological and fishery indicators of the fishery and assess its current status. The indicators currently being monitored for cuttlefish in South Australia are: a) the temporal and spatial variation in annual total catch, catch rate and targeted fishing effort in the commercial fishery; and b) estimates of annual total abundance and biomass of cuttlefish at the main spawning grounds, derived by fisher-independent surveys.

The total commercial catch of cuttlefish in South Australia declined from 150t in 1998 to 14t in 1999. This was due to the closure of the main fishery in the Black Point to Point Lowly area of northern Spencer Gulf. The area accounts for 92-98% of the total catch of the State. The abundance and biomass of cuttlefish in the area was monitored throughout the 1998 and 1999 spawning seasons using underwater visual counts. The total estimated biomass was 220t in 1998, and 211t in 1999. The targeted commercial catch in the area in 1997 was 235t. These estimates suggest a declining population, however, the decreases in biomass were only slight with respect to the large standard errors associated with the estimates.

1999 represents only the second year of research and monitoring on cuttlefish, and as yet significant aspects of the life history which may influence our estimates of abundance and biomass remain unresolved. Consequently, the status of the South Australian commercial cuttlefish fishery remains uncertain following the 1999 stock assessment.

1.2. Major findings

The key findings relating to the biological performance indicators were:

1. Very low levels of catch and effort were reported from the commercial fishery in 1999, when the spawning aggregation area was closed to fishing. Therefore, there is minimal targeted fishing for cuttlefish in South Australia in the absence of fishing on the spawning aggregation.

2. In the absence of fishing on the aggregation in 1999, the total estimated biomass in those areas fished during the 1998 season increased by 150% from 60t in 1998 to 152t in 1999. The estimated biomass in the closed area changed little from the 1998 estimate, and still only accounted for 26% of the estimated total biomass even though it represented around 44% of the available reef in the area.

3. Total surveyed abundance increased in 1999 by over 100,000 animals from 119,000 in 1998 to 220,000 in 1999. Most of this increase in abundance was in the area fished in 1998 but closed to fishing in 1999. Although this increase appears dramatic, there is no way of knowing what the total level of abundance in the area might have been in 1998 had fishing not occurred. We also do not know how these abundances compare with the virgin unfished abundance levels that occurred in the aggregation area prior to fishing. Given these uncertainties, we cannot conclude whether the levels of fishing reported in 1997 and 1998 were sustainable.

4. The total estimated biomass in 1999 for the aggregation area was 211t, which was slightly less than the 220t estimated for 1998. In 1997, no assessment of the spawning aggregation was undertaken, but a commercial catch of 235t was harvested from the area. Although, these

numbers suggest a declining biomass, the decreases were only slight (4-6%) and their associated standard errors were relatively large (14-46%).

1.3. Management implications

The increases in surveyed abundance and biomass in the previously fished area in 1999 when fishing did not occur, demonstrate how vulnerable the spawning aggregation is to intense fishing effort for even short periods of time. In addition, individual licence holders have the potential to take very large catches, so limiting the number of licence holders alone, would be unlikely to reduce the overall catch. The best method of controlling fishing effort is likely to be through a continuation of the current policy of time and area closures, which ensure a large percentage of the spawning biomass is protected and allowed to spawn each year.

Due to the likely semelparous life history of the species (i.e. spawn once and die) there is unlikely to be any spawning stock carried over from one year to the next. Therefore, the biomass of the subsequent year largely depends on successful recruitment from the previous year (Rosenberg *et al.* 1990). Consequently, overfishing in one year could cause recruitment failure in the next, and thus have a detrimental effect on the persistence of the stock (Beddington *et al.* 1990).

Cuttlefish currently attract a low price, which means that large catches are required for economic viability. Although there may be opportunity to increase the unit value of the catch, there are other stakeholders who gain economic return from the aggregation not being fished. These include the recreational dive and tourism sectors, and the film and television industry, who are attracted to the unique nature of the aggregation.

1.4. Principle uncertainties

The method currently used to estimate total abundance and biomass relies on the assumption that most animals arrive in the aggregation area before any start to leave, such that there is a peak level of abundance and biomass at some point that can be surveyed and estimated. If there is a constant turnover of animals in the area throughout the season as some evidence suggests, the method would vastly underestimate the true abundance and biomass visiting the area over the course of the spawning season.

In either event, the current method of surveying abundance and biomass provides conservative estimates which are useful as relative indices so long as the average residence time of animals does not vary from year to year. However, it would be inaccurate to add the cumulative catch onto the estimate of surveyed biomass to obtain an estimate of total biomass if there was a constant turnover of animals in the area.

The level of spawning biomass required to successfully spawn each year to maintain the population at an ecologically sustainable level is unknown. Therefore, the level of time or area closures needed to protect an adequate percentage of the spawning biomass also remains unknown.

1.5. Summary statistics

Table 1a. Comparison of total catch and targeted catch and effort for entire State. (1999 data to June only).

Year	Total Catch: Catch (tonnes)	Total Catch: No. of Fishers	Targeted Catch & Effort: Catch (tonnes)	Targeted Catch & Effort: Effort (fisher days)	Targeted Catch & Effort: No. of Fishers
1997 - Unrestricted	262	63	253	919	33
1998 – Main area closed early	150	58	146	535	30
1999 – Main area closed all season	14	36	11	78	10

Table 1b. Comparison of total catch and targeted catch and effort for Block 21. (1999 data to June only).

Year	Total Catch: Catch (tonnes)	Total Catch: No. of Fishers	Targeted Catch & Effort: Catch (tonnes)	Targeted Catch & Effort: Effort (fisher days)	Targeted Catch & Effort: No. of Fishers	Targeted Catch & Effort: % of Statewide Targeted Catch
1997 - Unrestricted	241	28	235	841	28	93%
1998 – Main area closed early	146	25	145	519	24	99%
1999 – Main area closed all season	11	9	11	65	7	100%

1.6. Biological indicators

Table 2. Comparison of abundance and biomass estimations for 1998 and 1999 seasons.

Area	1998: Abundance (numbers)	1998: Biomass (tonnes)	1999: Abundance (numbers)	1999: Biomass (tonnes)
TOTAL SURVEYED CLOSED AREA ± SE (%error of total estimated)	51,273	51 ± 10 (20%)	57,799	54 ± 25 (46%)
TOTAL SURVEYED FISHED AREA ± SE (%error of total estimated)	67,700	60 ± 12 (20%)	162,284	152 ± 21 (14%)
TOTAL SURVEYED Black Point to Point Lowly Area	118,973	111	220,083	207
CUMULATIVE CATCH (Block 21) Biomass removed from FISHED AREA		109		#4
GRAND TOTAL Black Point to Point Lowly Area		220		211

Amount removed as catch from Block 21 in 1999 – potentially from Fitzgerald Bay and the BHP Wall at Whyalla.

1.7. Resource users

Table 3a. Resource users – Commercial fishery sector. (1999 data to June only).

Year	Number Fishers	Total Catch	Value *
1997 - Unrestricted	63	262 t	$333,200
1998 – Main area closed early	58	150 t	$193,400
1999 – Main area closed all season	36	14 t	$19,500

* Value estimates based on average monthly prices paid by processors to fishermen.

Table 3b. Resource users – Processing and export sector. (1999 data to June only).

Year	Number Processors	Value *
1997 - Unrestricted	9	$130,000
1998 – Main area closed early	8	$75,000
1999 – Main area closed all season	<5	$7,000

* Value estimates based on $0.50 profit made per kg of cuttlefish caught.

Table 3c. Resource users – Recreational diving and tourism sector.

Year		Number of Visitors	Number of Dives	Value *
1997	- Non-local visitors (directly as result of cuttlefish)	420	1260	$55,000
	- Local		900	$12,000
	- Film crews (expenditure)	2		$36,000
1998	- Non-local visitors	112		$12,000
	- Local			$6,000
	- Film crews	3		$18,000
1999	- Non-local visitors			$8,000
	- Local			$10,000

* Value estimates from Tony Bramley, Whyalla Diving Services.

Table 3d. Resource users – Other sectors - 1999

Sector	Numbers	Value	Details
Recreational fishermen	No data	No data	
Scientific Interest - Australian	8	Non-profit	Graduate students & scientists
Scientific Interest - International	3		Collaborative Projects
Film/Television Industry	2	$10,000*	Sequence of footage sold locally
		$100,000*	Whole program distributed locally
		$1,000,000*	Major feature distributed world-wide
Public Interest	37,849	Non-profit	Number hits on "Cuttlefish Capital" Internet Site (June – Oct 99)

* Value estimates from Glen Carruthers, Green Cape Wildlife Films (filmed cuttlefish in 1999 and plans to return in 2000).

2. BACKGROUND

2.1. Description of the fishery

The main fishery targeting cuttlefish in South Australia is based on the annual spawning aggregation of *Sepia apama* in the waters adjacent to Black Point and Point Lowly (henceforth referred to as the aggregation area) in northern Spencer Gulf (occurs within the Block 21). The area covers approximately 8km of coastline, and the cuttlefish occur in less than 8m of water over the inshore rocky reef habitat. The majority of the catch is taken between May and July when thousands of cuttlefish aggregate in the area to spawn.

Cuttlefish are targeted using lines and squid jigs in the shallow inshore waters (<200m offshore). Vessels used in the fishery are generally the multi-purpose ones used for other marine scalefish fishing, typically 5-8 metres in length. Up to 4-5 fishers operate from the one vessel. The use of larger sleeping vessels in combination with smaller dinghies was observed in the 1998 season.

The commercial cuttlefish catch taken outside of the aggregation area is usually taken as by-catch by squid jigs and lines, and in haul nets, gill nets and rock lobster pots, throughout the State.

Recreational fishers rarely target cuttlefish and they are usually only taken as by-catch by anglers who are targeting southern calamary (*Sepioteuthis australis*), as both species are caught using similar lines and jigs.

2.2. Management

The commercial cuttlefish fishery in South Australia is currently managed under the broad management framework of the commercial marine scalefish fishery. Before 1998, there were no specific management controls in place for the taking of this species. However, prior to the start of the 1998 fishing season, a time and area closure within the main spawning ground was introduced, in an attempt to protect some of the spawning population in the aggregation area. From 1 March 1998 to 30 September 1998, it was unlawful for any person to engage in any fishing activity within Spencer Gulf waters enclosed by the following boundaries:

> from the Point Lowly lighthouse to the southern end of the Port Bonython jetty, then to the seaward end of the western boundary fence of the SANTOS facility, and from there following the high water mark eastwards along the shoreline back to the lighthouse (fig. 1).

This closure was found to cover approximately 44% of the reef habitat in the aggregation area (Hall and McGlennon 1998).

During the 1998 fishing season, concerns were raised regarding the level of spawning biomass protected by this closed area. In addition, an increase in fishing effort in the open area was observed. Consequently, the entire aggregation area was closed to fishing from 11 June 1998 until 30 September 1998:

> the taking of cuttlefish was banned in all waters of the Spencer Gulf enclosed by a line from the lighthouse at Point Lowly to the southern end of the Port Bonython jetty, then in a south westerly direction to the southern end of the BHP wall near Whyalla then follow high water mark along the shoreline in an easterly direction to the point of commencement at the lighthouse (fig. 1).

S. apama displays a similar migratory life cycle in northern Spencer Gulf (fig. 2). Numbers also increase in other coastal areas during winter months (May to August) when spawning occurs (Gales *et al.* 1993, Rowlings 1994, Nute A. 1998, pers. comm.). Some variation to this general winter spawning period may exist, e.g. mature specimens have been collected from Gulf St. Vincent in spring, suggesting some out-of-season spawning for that Gulf.

Female *S. apama* attach their eggs to the underside of rocks, ledges, caves and crevices in subtidal reef habitats (Moran 1998). The necessity for suitable hard substrate for the attachment of eggs may drive the inshore migration for spawning (Hall 1998). The presence of a suitable prey species or habitat for juveniles may also be other possible contributing factors.

It is not known from where the cuttlefish migrate nor the distances travelled to reach the inshore spawning areas. Widely but sparsely distributed adults are caught by prawn trawlers throughout northern Spencer Gulf during the summer (Carrick unpub. data). These animals are not sexually mature and frequently have full stomachs indicating they were feeding.

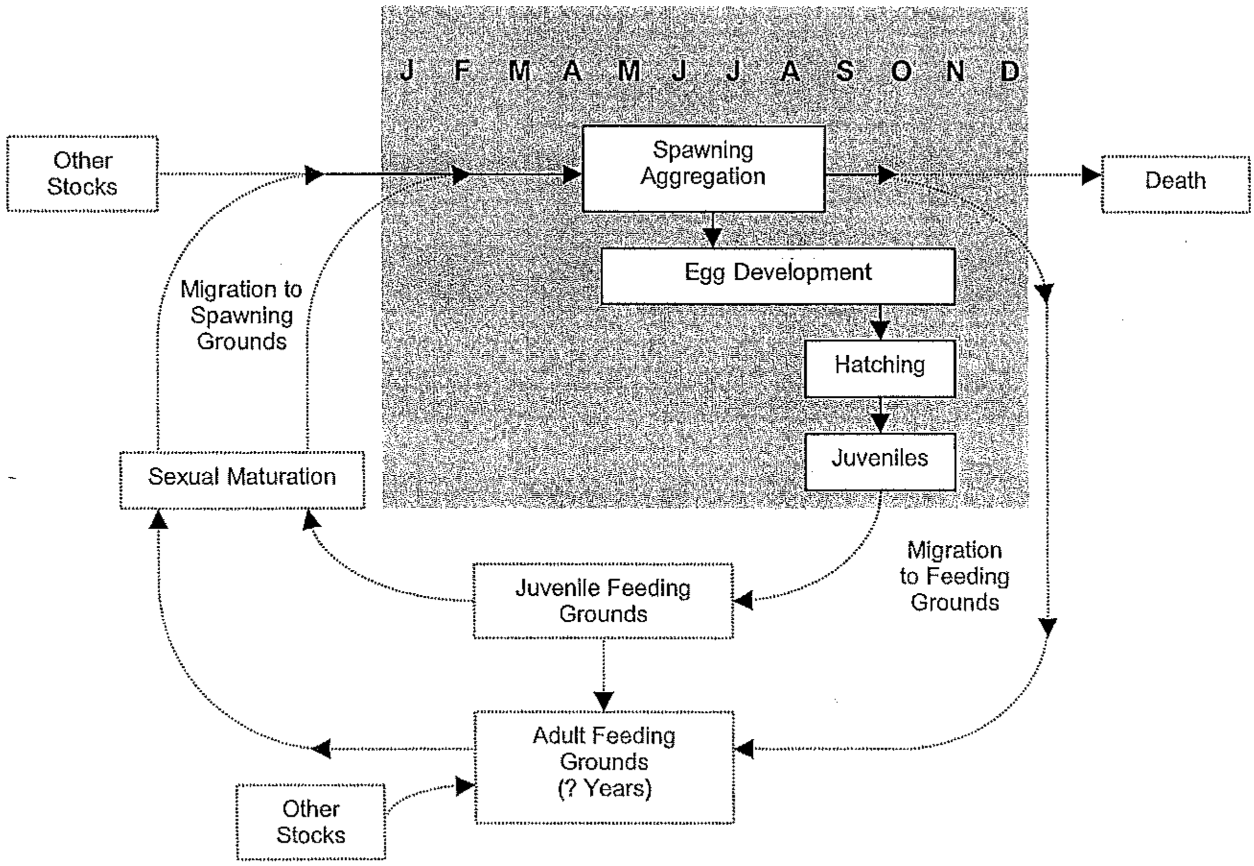


Figure 2. Schematic representation of the possible phases of the life cycle of *Sepia apama* spawned in the aggregation area. The shaded area represents known phases of the life cycle that occur in the aggregation area, the timing of which is indicated in the calendar above. Dashed lines represent other proposed life history processes and stages.

Population structure

The population structure of *S. apama* in southern Australian waters is not known. The spawning aggregation in the Black Point to Point Lowly area appears to be the only one that occurs across the entire distribution. The unique social behaviour of animals in the spawning aggregation, suggests it might constitute a population that is reproductively isolated from other populations in South Australian waters (Hall and McGlennon 1998).

Reproductive biology

Female *S. apama* spawn large (11-18mm diameter), yolky eggs which are encased in a gelatinous protective casing and laid individually. The size of mature eggs is proportional to the size of the female (Hall and McGlennon 1998). Larger females also possess larger ovaries, suggesting they may have greater reproductive output potential than smaller ones.

Fecundity is difficult to estimate for cuttlefish, but is considered to be relatively low (in the order of 100 to 1,000) compared to broadcast spawners like many fish species (Boyle 1990). The reproductive system of female *S. apama* consists of a single ovary, where eggs develop, and an oviduct, where mature eggs accumulate until spawning occurs. Within the ovary a wide range of developmental stages of immature eggs were found, even when mature eggs were present in the oviduct. Therefore, it may be possible for females to spawn more than one batch of eggs in a season, and possibly over an extended period of time (perhaps the entire spawning season). It is not yet known how many immature eggs in the ovary actually reach maturity during the spawning season and over what time period an individual female may keep spawning. It does, however, suggest a prolonged spawning strategy for this species (Hall and McGlennon 1998).

Size and age structure

The size and age at sexual maturity and potential longevity for any given species of cephalopod is strongly influenced by temperature (Forsythe and Hanlon 1988). Animals reared at higher temperatures (even 5°C higher), tend to grow faster, reach larger sizes, mature younger and have shorter life spans than conspecifics reared at lower temperatures.

A range of size classes of males and females were recorded within the spawning aggregation despite the fact this is thought to be an annually spawning, semelparous species. This reproductive strategy usually results in a population consisting of one cohort with a single size mode. All animals were sexually mature and potentially spawning. Either the different size classes represent individuals from the one stock maturing at different ages (fig. 3a); or similarly-aged individuals which have attained different sizes due to differences in feeding, temperature etc. during their growth and maturation periods (fig. 3b); or individuals from different stocks which have different ages or growth patterns (fig. 3c).

The only ageing work completed on *S. apama* to date, used the simple method of measuring the diameter of the freshly dissected eye lens (Hall and McGlennon 1998). There were several modes in eye lens diameters from female and male specimens collected from Black Point. Although this method is rather crude, it suggests there could be more than one cohort or generation present in the spawning aggregation.

Longevity

The longevity of *S. apama* is not known; however, it is commonly thought to be semelparous (Gales *et al.* 1993, Anon. 1993). Large numbers of cuttlebones and carcasses wash up onto various beaches around South Australia and in other southern States during the late winter months, which is assumed to relate to mass mortality events following spawning (Lu 1998). Semelparous cephalopod species commonly undergo a decline in condition during or following exhaustive spawning which ultimately results in death (Mangold 1987). However, no obvious decline in condition indices was detected for animals collected from the aggregation towards the end of the spawning season (Hall and McGlennon 1998).

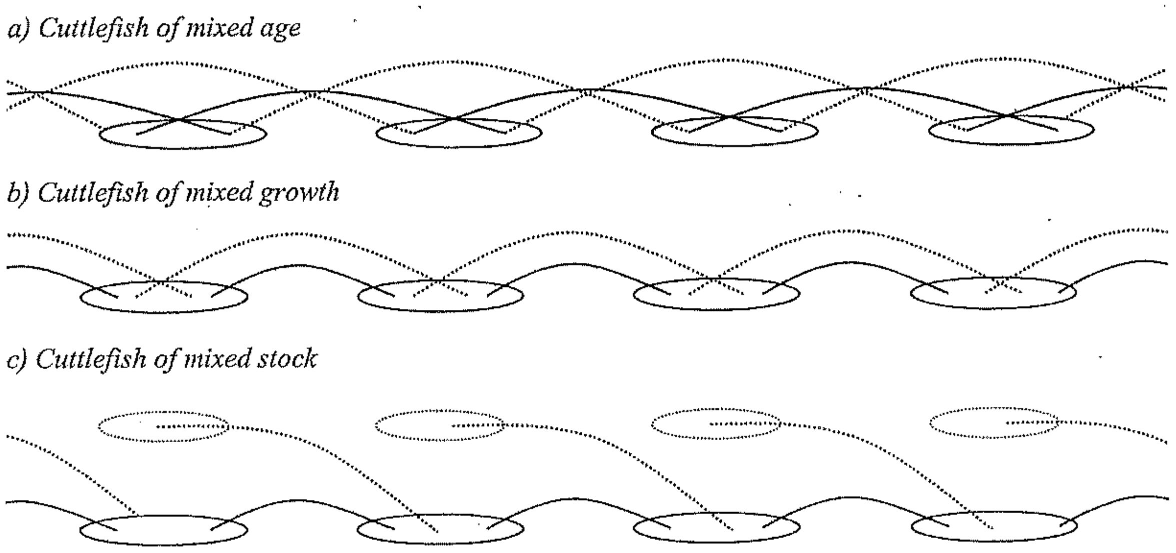


Figure 3. Diagrammatic representation of three alternative hypotheses to account for two size modes at maturity in an annually spawning, semelparous species. Annual spawning period is represented by the oval shape, solid lines indicate origin of small size mode, and dashed lines the origin of larger sized cuttlefish. (Original diagram proposed by Boyle *et al.* (1995) for squid *Loligo forbesi*).

Egg development and recruitment

There is no parental care of the eggs with most adult cuttlefish disappearing from the spawning grounds before the first eggs fully develop.

The time taken for eggs to develop largely depends on water temperature (Hall and McGlennon 1998). Eggs laid at the start of winter take the longest time to develop (approximately 4 months) as most development takes place in cold water temperatures. Eggs laid towards the end of the season develop faster (approximately 2 months) due to increasing water temperatures. Hatching starts around the end of August and finishes around the end of October.

Field observations strongly suggest that sea urchins may eat or dislodge developing eggs. Urchins were often found underneath rocks surrounded by numerous stumps of eggs and some had partially consumed eggs in their mouth-parts. There are very high densities of urchins in the aggregation area which could impact on egg survival. Hatchlings were also preyed upon by small fish as soon as they emerged from their protective casings.

Little is known about the growth and movement of juveniles following hatching. Juveniles maintained in aquaria grew rapidly and fed voraciously on mysids and other small shrimp (Hall unpub. data). Their growth rates in captivity suggest that juveniles spawned in one season may grow fast enough to reach maturity in the following season. However, they would only reach the smallest size classes observed in the spawning population (i.e. 10-15cm mantle length), by the start of the following spawning season.

3. CURRENT MONITORING AND RESEARCH

3.1. Overview

The biological and fishery indicators currently being monitored for cuttlefish in South Australia are:

- temporal and spatial variation in total catch, catch rate (CPUE) and targeted effort in the commercial fishery;
- estimates of the annual total abundance and biomass of cuttlefish in the aggregation area derived from fisher-independent surveys.

3.2. Commercial fishery catch and effort

Catch

The historical total annual catch of cuttlefish (*Sepia apama*) taken by the commercial fishery in South Australia is shown in figure 4a. The total catch produced from Block 21 is also shown, as it accounts for most (92-98%) of the total catch of the State. Block 21 includes the aggregation area in northern Spencer Gulf where the main cuttlefish fishery operates.

Note that catch and effort data for this species refer to calender years, in contrast to the general reporting of financial years. This is done to more accurately represent the main fishing season of April to July each year. For this reason, 1999 data only include catches to June. The total catch also includes non-targeted catch.

Total catch increased dramatically from 1993 to 1997 (fig 4a). In 1997, a peak catch of 262t was reported, followed by a considerably smaller catch of 150t in 1998 and then only 14t in 1999. The sudden drop in catch in the last two years can be attributed to the early closure of the main fishery in Block 21 during the second week of June in 1998, and the total closure of the main fishery for the duration of the spawning season in 1999 (between 1 March 1999 to 30 September 1999).

Effort

The trend in annual targeted fishing effort in the commercial fishery, follows the trend in total catch (fig. 4b). Effort expressed as fisher days is calculated by multiplying the number of boat days recorded by each licence holder by the number of fishers operating from each vessel on any given day. Fishing effort increased from 1993 to a peak of 919 fisher days in 1997, then declined to 535 fisher days in 1998 and only 78 fisher days in 1999. Therefore, there was minimal targeted effort on cuttlefish in the State when the aggregation area was closed to fishing.

CPUE

CPUE for Block 21 increased from 115 kg/fisher day in 1995 to a peak of 280 kg/fisher day in 1997 and 1998, then decreased by 40% to 169 kg/fisher day in 1999 (fig. 4c). The lower CPUE in 1999 possibly reflects the lower densities of cuttlefish present outside the aggregation area.

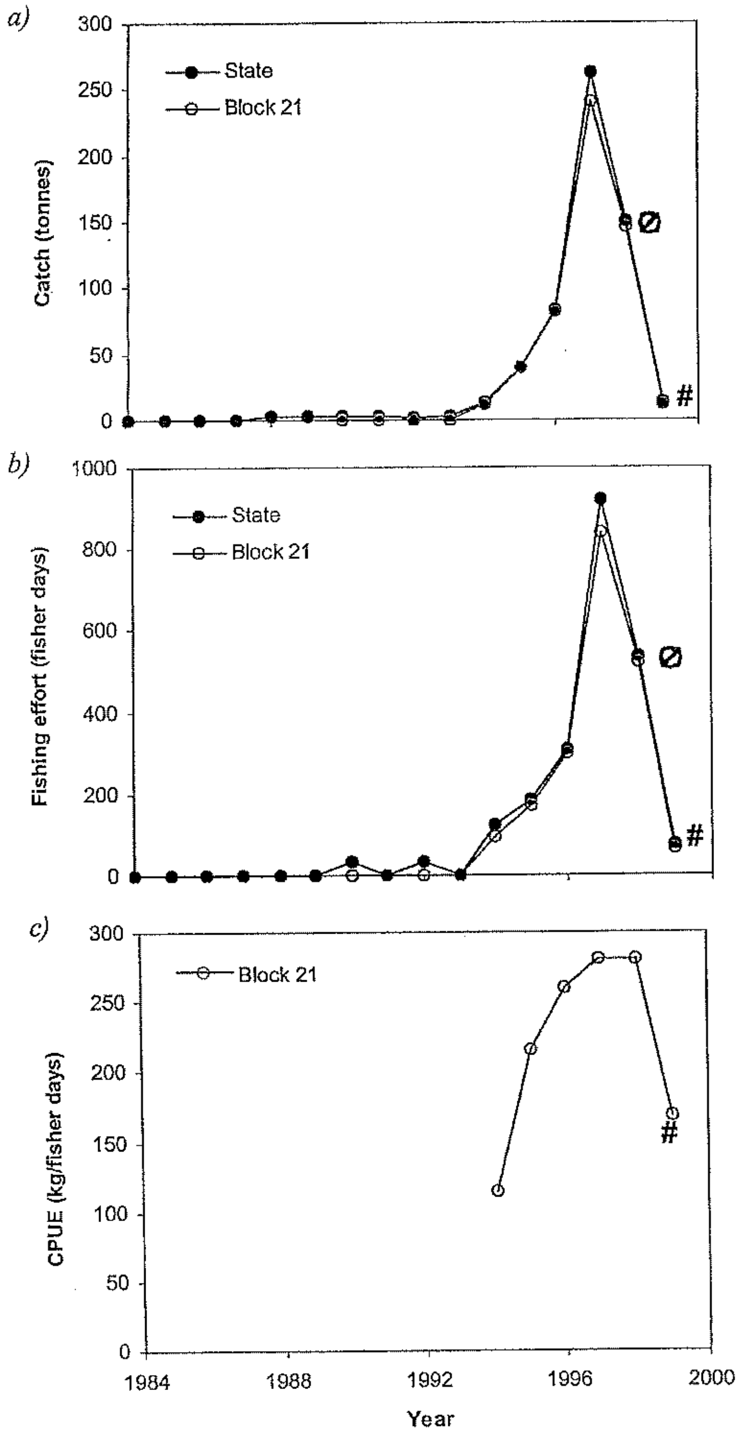


Figure 4. Annual total commercial catch (a), effort (b) and CPUE (c) of cuttlefish for South Australia and Block 21. NB: The main fishery was closed early in 1998 (⊘) and all season in 1999 (#).

Distribution of catch within State

The majority of the targeted catch for the State (93-100%) is taken from Block 21 (Table 4). In 1999, 99% of the targeted catch of 11t was taken from Block 21 even though the spawning aggregation was closed to fishing. This catch was presumably taken from areas adjacent to the main spawning grounds. Other areas where cuttlefish were targeted in 1999 and the general magnitude of catches reported from around the State are shown in figure 5.

Table 4. Comparison of total catch, targeted catch and number of licence holders for South Australia and Block 21. (1999 data to June only).

	Total Catch		Targeted Catch				
	State		State		Block 21		
Year	Catch (tonnes)	No. of Fishers	Catch (tonnes)	No. of Fishers	Catch (tonnes)	No. of Fishers	% of Statewide Targeted Catch
1994 - Unrestricted	12.4	34	11.0	14	10.9	8	99%
1995 - Unrestricted	39.9	38	36.6	15	36.3	10	99%
1996 - Unrestricted	82.6	48	77.3	15	77.2	13	100%
1997 - Unrestricted	262.1	63	253.5	33	235.5	28	93%
1998 - Closed early	150.2	58	145.9	30	145.5	24	100%
1999 - Not opened	13.7	36	11.1	10	11.0	7	99%

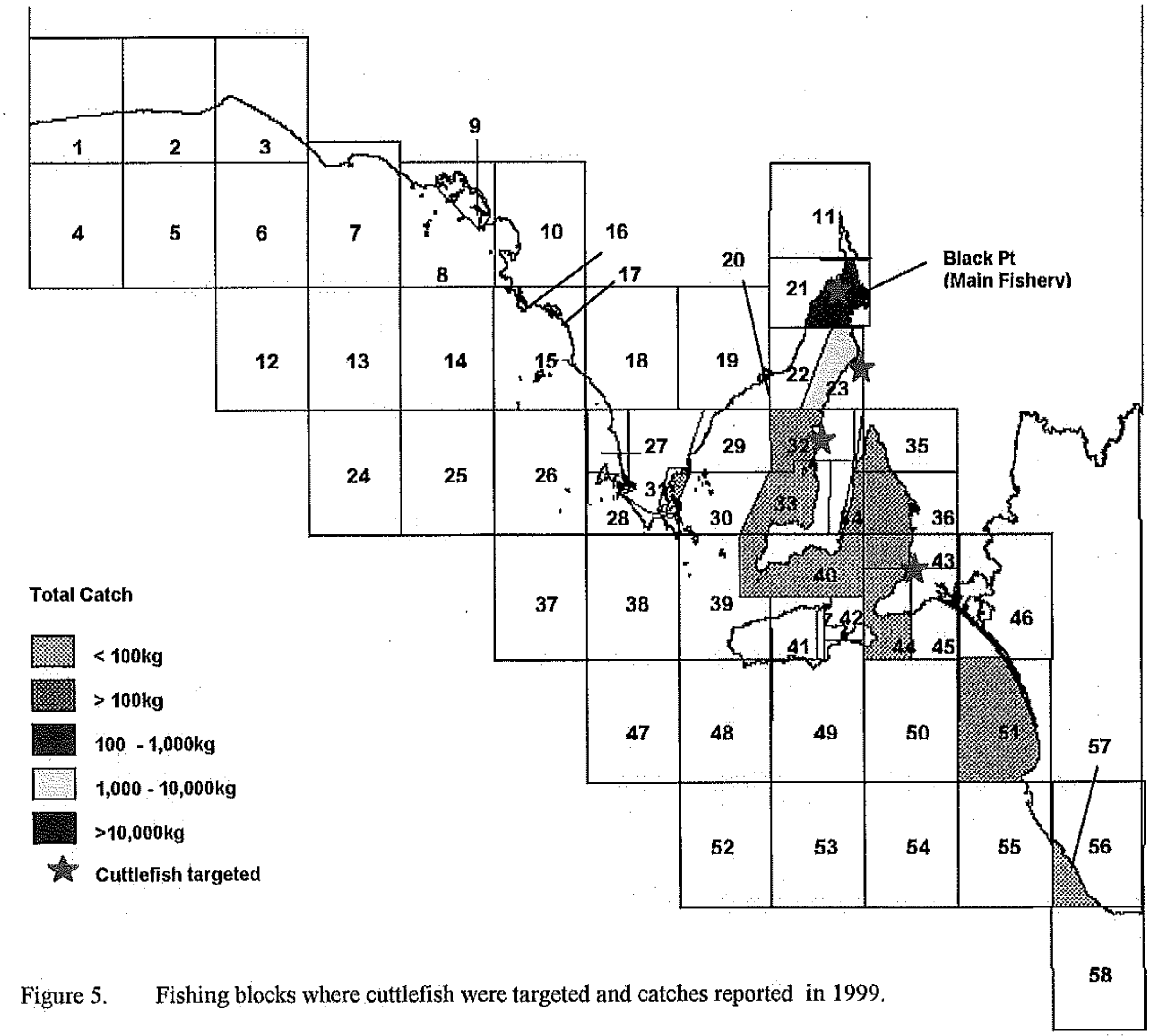


Figure 5. Fishing blocks where cuttlefish were targeted and catches reported in 1999.

Distribution of catch between licence holders

There was a substantial decline in the number of licence holders targeting cuttlefish in 1999 (table 4). Only 7 of the 36 licence holders who reported catches in 1999, actively targeted the species, which represents only a quarter of the number targeting cuttlefish in 1997 when there were no restrictions on taking cuttlefish in place.

Most licence holders in 1999 reported individual catches of less than 5t (table 5). However, in previous years a small proportion of the total number of licence holders in the State took the bulk of the catch. In 1997, seven fishers reported catches of over 15t, and their combined catch was 150t accounting for 57% of the total catch of the State. This compares to the entire catch of the State in 1998 of 149t. Therefore, limiting the number of licence holders in the fishery alone, would be unlikely to reduce the overall catch.

Table 5. Distribution of total catches of cuttlefish in South Australia between licence holders for the last four years. (1999 data to June only).

Catch Range		1996	1997	1998	1999
< 5t	No. licence holders	42	46	45	36
	Combined catch	19t	28t	24t	14t
	% of total catch	23%	16%	16%	100%
5 – 15t	No. licence holders	6	10	13	<5*
	Combined catch	63t	71t	125t	
	% of total catch	77%	27%	84%	
> 15t	No. licence holders		7	< 5*	
	Combined catch		150t		
	% of total catch		57%		

* NB: In 1998, less than 5 licence holders reported catches greater than 15t and in 1999, less that 5 licence holders reported catches greater than 5t. These catches were included in the lower catch category for confidentiality reasons.

Seasonality of catch and effort

The cuttlefish fishery of South Australia is very seasonal, reflecting its dependence on the spawning aggregation in the Black Point to Point Lowly area. Most catch is taken in the first two months (May and June) of the spawning season (fig. 6a).

The highest monthly catch rates are also reported in May and June (fig. 6b), corresponding to the time when cuttlefish are in their highest densities within the spawning aggregation. The average catch rate achieved in June of 1999 was well below those for the same month in previous years.

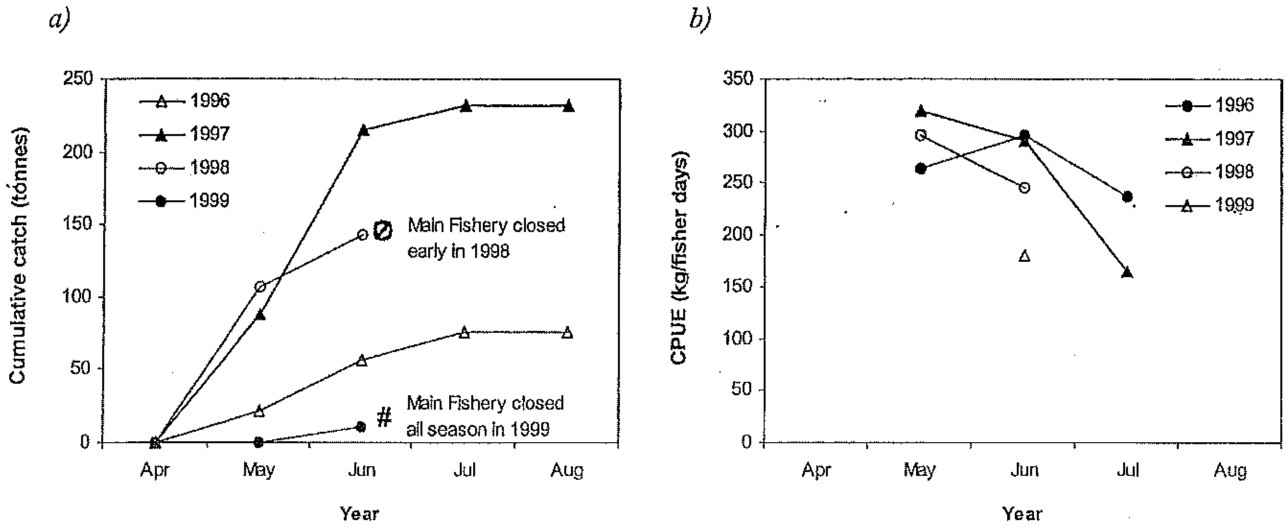


Figure 6. Monthly cumulative targeted catch (a) and CPUE (b) of cuttlefish from Block 21 for the last 4 years. (1999 data to June only).

3.3. Abundance and biomass estimation

Spatial and temporal changes in the annual abundance and biomass of *S. apama* in the aggregation area were monitored in 1998 and 1999 using underwater visual counts. These data were used to generate simple abundance and biomass models for the spawning aggregation and assess the stock for any changes that may relate to fishing.

1998 Survey design

Before the 1998 fishing season, an area of coastline near the Port Bonython jetty (from Stony Point to the tip of Point Lowly) was closed to fishing to protect some spawning biomass in the absence of other management controls. Several sites within both the closed area and the area remaining open to fishing were monitored throughout the spawning season (fig. 7).

Habitat surveys were completed prior to the start of the spawning season to quantify the area of subtidal rocky reef habitat available in the closed and fished areas. Two main reef habitat types were identified - solid rock/reef habitat dominated by urchins close to the shoreline (referred to as the "urchin habitat"), and patch reef habitat dominated by tall algal stands and razorfish further from the shore (referred to as the "algae habitat").

1999 Survey design

In 1999, the area west of Point Lowly to Whyalla was closed to fishing for the entire spawning season.

The results of the 1998 survey indicated cuttlefish were not evenly distributed within the aggregation area. Higher densities were recorded at Site 1 in the fished area (Black Point) and Site 1 in the closed area (Stony Point) and there were consistently more cuttlefish found in the "urchin habitat", than the "algae habitat" at all sites and times.

Therefore, in 1999 the temporal survey was reduced to monitor only the "urchin habitat" at four sites, including Black Point and Stony Point. Only one complete spatial survey of all sites was conducted at the end of May, to coincide with the maximum level of biomass in the spawning aggregation.

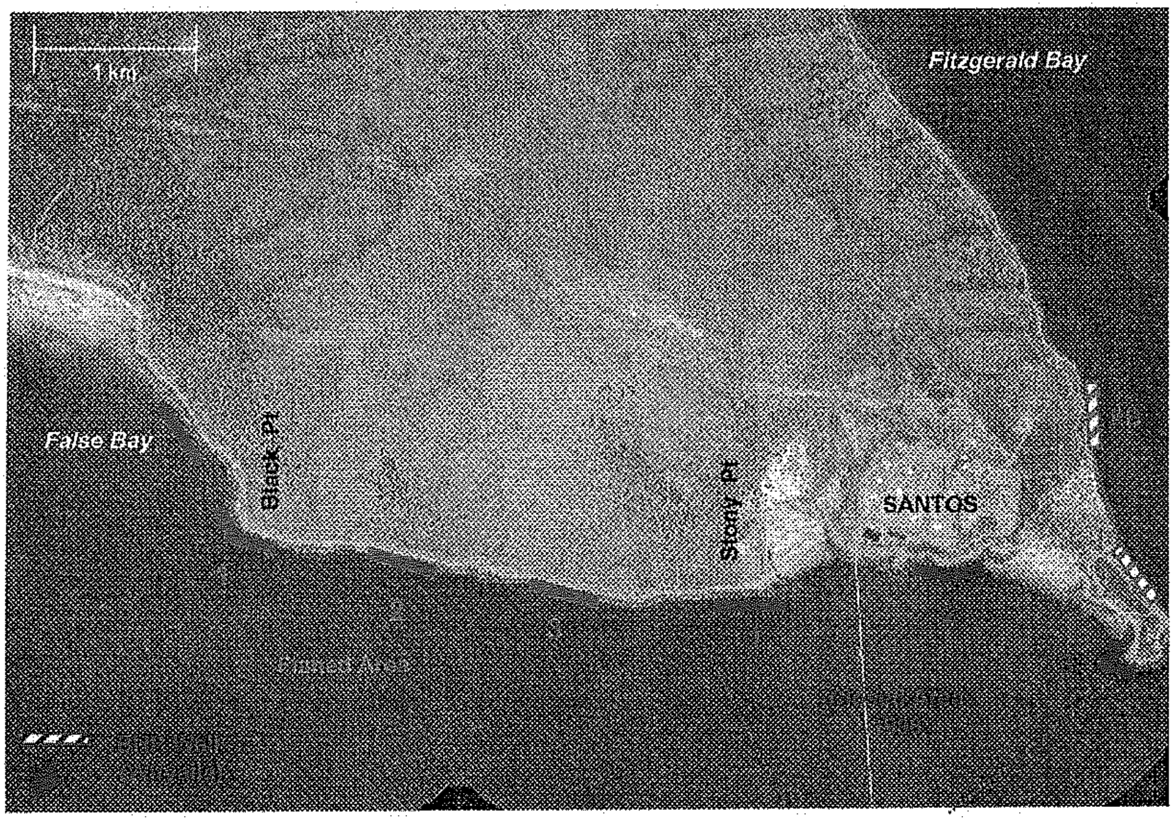


Figure 7. Location of sampling sites in the Black Point to Point Lowly area.

Survey methods

Four 2x50m transects were completed in each habitat type at each site and time, providing an estimate of average density per 100 m^2. An estimate of the average weight of cuttlefish per 100 m^2 was also calculated by converting the length estimate recorded for each cuttlefish to weight using the appropriate length-weight relationship. Validation of length estimates and sex determinations was achieved by the removal of animals following estimation, for verification of lengths and sexes in the laboratory.

Abundance estimates

Abundance estimates were calculated for each site by multiplying the average density of cuttlefish for each site by the appropriate estimate of reef area. Total surveyed abundance in the fished area and the closed area were estimated by combining the abundance estimates for all fished and closed area sites, respectively.

Biomass estimates

A biomass estimate for each site was calculated by multiplying the average weight of cuttlefish per unit area by the corresponding reef area estimate. Total surveyed biomass in the fished and closed areas were estimated by combining the abundance estimates for all fished and closed area sites, respectively. The cumulative commercial catch was added onto the estimate of biomass for the fished area to provide an estimate of what the total biomass in the fished area might have been had fishing not occurred. By combining this with the estimate of total biomass in the closed area, an estimate of total biomass in the aggregation area was obtained.

3.4. Results of 1998 and 1999 stock assessments

A summary of the findings of the two stock assessments for *Sepia apama* in the spawning aggregation area is given below. In 1998, about 56% of the aggregation area was left open to commercial fishing for 32 days at the start of the spawning season, but in 1999 the whole area was closed to fishing for the entire spawning season. Therefore, the 1999 results are compared to the 1998 results where possible to identify differences that may relate to fishing.

Reef area estimates

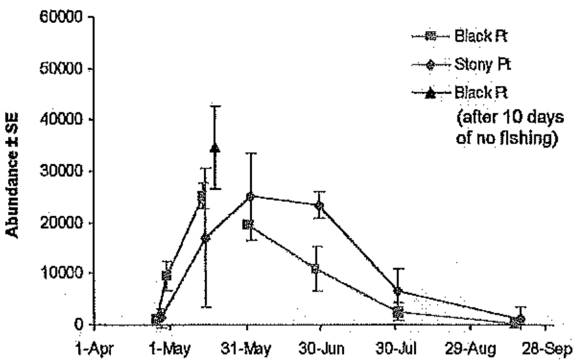
The area of reef in the aggregation area closed to fishing at the commencement of the 1998 fishing season was estimated to be 3.4 hectares which represented 44% of the total reef available. The area of reef remaining open to fishing was estimated to be 4.3 hectares which represented 56% of the total reef area.

Abundance estimates

In both years, cuttlefish began arriving in the aggregation area in the last week of April and rapidly increased in numbers during May. Then by the end of August, nearly all cuttlefish had left the area. Densities of cuttlefish present before and after the spawning season were very low (less than one per 100 m^2).

The abundance estimates for the two main sites in 1998, Black Point in the area left open to fishing and Stony Point in the area originally closed to fishing, are shown in figure 8a. At Black Point there was an initial rapid increase in numbers followed by a gradual decline throughout the remainder of the season. At Stony Point there was a more gradual increase in numbers and the decline in numbers did not start until later in the season.

a) 1998



b) 1999

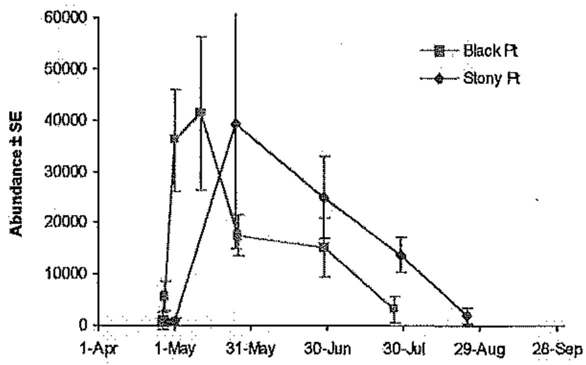


Figure 8. Total abundance estimates for the two main sites at various times during the 1998 and 1999 spawning seasons.

In 1999, when neither site was fished a similar temporal pattern was observed at both sites (fig. 8b). At Black Point the abundance increased even faster during the first two weeks of May and reached a substantially higher abundance than in 1998, followed by a dramatic decline in late May and a more gradual decline from then on. At Stony Point the numbers also increased rapidly during May, reached a higher abundance than in 1998, and gradually declined through the remainder of the season.

There appears to be a peak in abundance from mid May to late May (fig 8). If most cuttlefish have arrived into the aggregation area before any start to leave, this peak in numbers should represent the maximum abundance of cuttlefish occurring in the area that season.

Table 6. Comparison of abundance and biomass estimates for 1998 and 1999 spawning seasons.

	1998		1999	
Area	**Abundance (numbers)**	**Biomass (tonnes)**	**Abundance (numbers)**	**Biomass (tonnes)**
CLOSED AREA				
Stony Pt	25,884	27	44,624	41
SANTOS Jetty (estimated)	7,042	7	1,386	1
SANTOS Tanks	12,495	12	2,264	2
Waroona Bay Reef (estimated)	13,738	1	236	0
Pt Lowly	1,389	1	1,286	1
BHP Wall	3,748	3	8,003	*8
TOTAL SURVEYED CLOSED AREA	**51,273**	**51**	**57,799**	**54**
± SE		± 10		± 25
Percent of TOTAL ESTIMATED BIOMASS		23%		26%
FISHED AREA				
False Bay – Black Pt	7,797	7	16,368	15
Black Pt	20,819	18	47,916	42
3rd Dip	15,859	13	31,370	29
West of SANTOS Boundary Fence	13,738	14	51,692	53
Pt Lowly – Boat Ramp	2,609	2	4,108	*4
Fitz Bay	6,878	5	10,830	*9
TOTAL SURVEYED FISHED AREA	67,700	60	162,284	152
± SE		± 12		± 21
Percent of TOTAL ESTIMATED BIOMASS		27%		72%
TOTAL SURVEYED Black Point to Point Lowly Area	**118,973**	**111**	**220,083**	**207**
CUMULATIVE CATCH (Block 21)		**109**		**†4**
Percent of TOTAL ESTIMATED BIOMASS		50%		2%
GRAND TOTAL Black Point to Point Lowly Area		**220**		**211**

* Sites that were open to fishing in 1999.
† Amount removed as catch from Block 21 in 1999 – potentially from Fitzgerald Bay and the BHP Wall at Whyalla.

Total surveyed abundance increased from 119,000 in 1998 to 220,000 in 1999 (table 6). Most of the increase in abundance was in the area fished in 1998 but closed to fishing in 1999. Although this increase appears dramatic, there is no way of knowing what the total level of abundance in the area might have been in 1998 had fishing not occurred. We also do not know how these abundances compare with the virgin unfished abundance levels that occurred in the aggregation area prior to fishing. Given these uncertainties, we cannot conclude whether the levels of fishing reported in 1997 and 1998 were sustainable.

Biomass estimates

In 1998, the estimated total biomass was 220t (fig. 9 and table 6), which consisted of 111 ± 15t of surveyed biomass (closed and fished areas combined), plus 109t of catch (accumulated until the biomass in the closed area started to decline) (see Hall and McGlennon 1998 for a full discussion of the calculation methods used).

The total estimated biomass in 1999 for the aggregation area was 211t, which was slightly less than that of 1998 (fig. 9). In 1997, no assessment of the spawning aggregation was undertaken, but 235t of cuttlefish were reported as harvested from the area (fig. 9). Although these numbers suggest a declining biomass, the decreases in biomass were only slight (4-6%) and their associated standard errors were relatively large (14-46%).

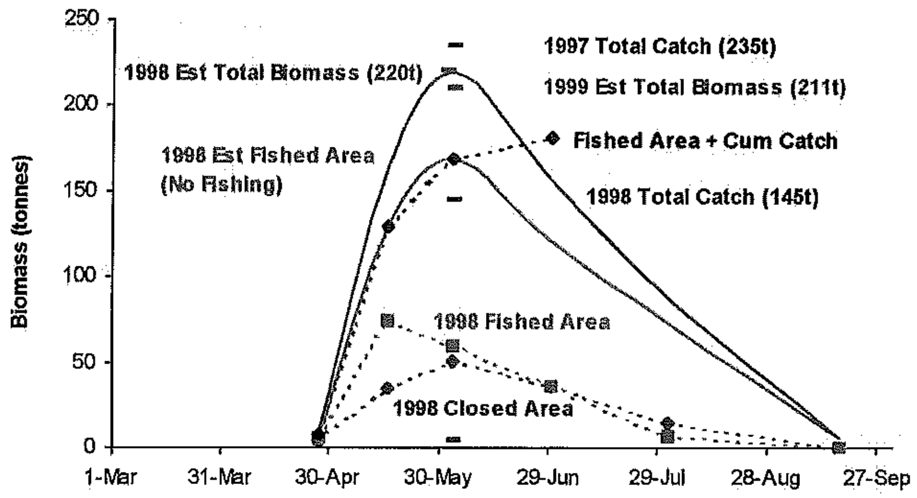


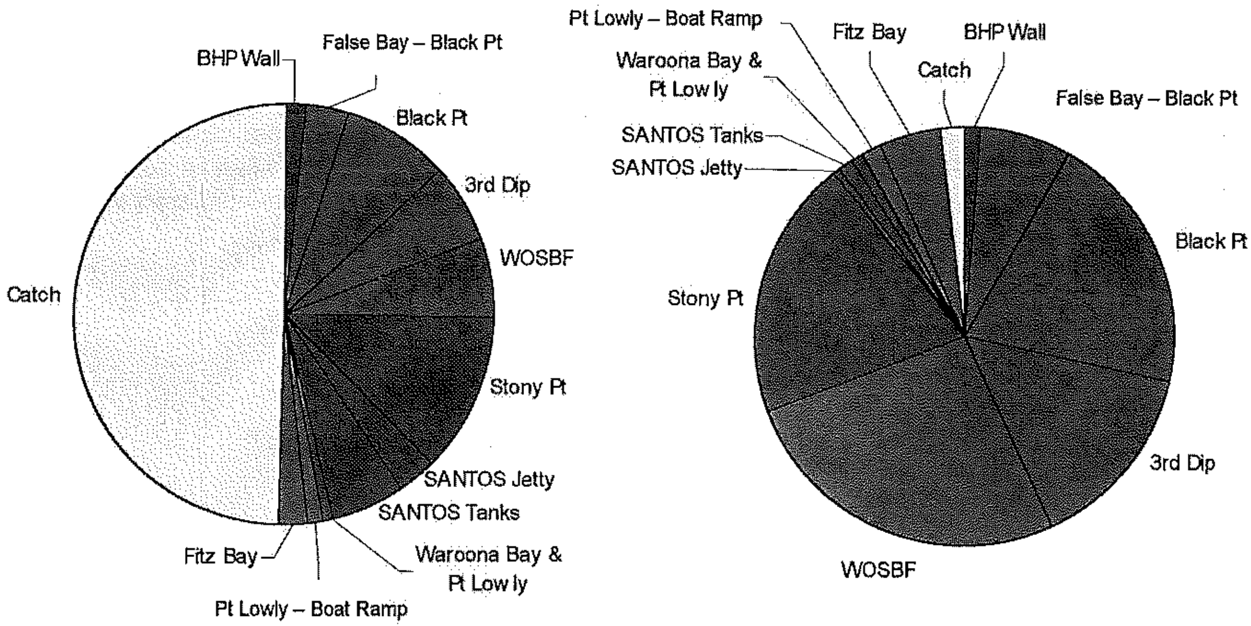
Figure 9. Temporal trends in the total estimated biomass for 1998 with total annual catches and the 1999 total estimated biomass overlayed (refer to section 3.5 for a discussion of assumptions involved in these biomass estimates).

Figure 10 shows the breakdown of the total estimated biomass according to individual sites monitored and the proportion removed as catch in 1998 and 1999. These estimates were derived from one overall spatial survey at the end of May each year. In 1998, the catch accounted for approximately 50% of the total estimated biomass, even with the main fishery closed early. This proportion was decreased substantially in 1999 through the total closure of the main fishery.

The estimated biomass in the closed area (indicated in green, fig. 10) changed little between seasons, accounting for only 23-26% of the estimated total biomass. However, there was a shift in the proportion of biomass found at each individual site, with biomass increasing at Stony Point but decreasing at the other sites (fig. 10b). The estimated biomass in the fished area (indicated in red, fig. 10) increased by 150% in 1999 when the sites were not fished, from 60t in 1998 to 152t in 1999 (table 6). This increase in biomass was consistent across all fished sites (fig 10b).

Figure 10. Breakdown of total estimated biomass according to sites monitored at the end of May each year.

a) 1998 – 220 tonnes *b) 1999 – 211 tonnes*



Movement Studies

Our original assumption was that most cuttlefish upon arrival into the spawning grounds found a mate, established a territory and remained in approximately the same spot for the duration of the spawning season. This was based on Rowlings (1994) study of the spawning behaviour of *S. apama* in the waters adjacent to Edithburgh in southern Gulf St. Vincent.

Rowlings found spawning males to be extremely territorial with a high site fidelity. Tagged cuttlefish were repeatedly observed occupying the same location on successive occasions through the spawning season. He likened it to the den ecology commonly observed for octopus. In addition, he observed the same suite of males present for the duration of the spawning season.

A substantial period of focal animal behavioural sampling was completed in May 1999 on the spawning aggregation in northern Spencer Gulf. Individual cuttlefish were followed for around an hour each and their behaviour recorded on video tape. The sampling revealed a very different pattern of behaviour to that originally assumed. Competition for females was fierce and there was a regular mixing and changing of pairs. The whole mating system was very dynamic. Males moved large distances in search of mates and females moved large distances (100's of metres) in search of egg laying sites.

A pilot tagging study done in 1999 within the original closed area at Stony Point verified that the cuttlefish within the aggregation were highly mobile. Animals moved from the closed area to open area and covered distances of up to 500m within 24 hours.

A more extensive tagging study is planned for the beginning of the year 2000 spawning season to better understand movement of cuttlefish within the spawning grounds during the season. This will also hopefully indicate the length of time spent at the spawning grounds by individual cuttlefish.

3.5. Reliability of assessment

The method currently used to estimate total abundance and biomass relies on the assumption that most animals arrive in the aggregation area before any start to leave, such that there is a peak level of abundance and biomass at some point that can be surveyed and estimated. The movement and behavioural studies discussed above suggest these assumptions may require modification. If there is a constant turnover of animals in the area the method would underestimate the true abundance and biomass of cuttlefish coming into the area over the course of the spawning season.

In either event, the current method of surveying abundance and biomass provides conservative estimates which are useful as relative indices so long as the average residence time of animals does not vary from year to year. However, it would be inaccurate to add the cumulative catch onto the estimate of surveyed biomass to obtain an estimate of total biomass if there was a constant turnover of animals in the area.

The level of spawning biomass required to successfully spawn each year to maintain the population at an ecologically sustainable level is unknown. Therefore, the level of time or area closures needed to protect an adequate percentage of the spawning biomass also remains unknown.

3.6. Future assessment needs

Continued estimation of the abundance and biomass of cuttlefish occurring in the spawning grounds each year is essential to provide pre-fishing estimates of the potential level of stock available to the fishery each year. A better understanding of the dynamics of the spawning aggregation in terms of turn-over rates and residence times in the area is required to make these estimates more accurate. Furthermore, an understanding of the relationship between the spawning biomass of one year and the recruitment to the fishery in subsequent years would help in determining appropriate reference values for the assessment of the biological and fishery indicators for cuttlefish.

The collection of catch and effort information on a finer temporal scale (ideally daily) is recommended to more closely monitor the exploitation rate during the relatively short fishing season.

4. MANAGEMENT IMPLICATIONS

4.1. Summary of findings

1. In 1998, about 56% of the aggregation area was left open to commercial fishing for 32 days at the start of the spawning season. The biomass in this fished area was estimated to be 62t. In 1999, this area was closed to fishing and the estimated biomass increased by 150% to 152t. This suggests that commercial fishing on the aggregation can rapidly impact on the spawning biomass.

2. Total surveyed abundance increased in 1999 by over 100,000 animals from 119,000 in 1998 to 220,000 in 1999. Most of the increase in abundance was in the area fished in 1998 but closed to fishing in 1999. Although this increase appears dramatic, there is no way of knowing what the total level of abundance in the area might have been in 1998 had fishing not occurred. We also do not know how these abundances compare with the virgin unfished abundance levels that occurred in the aggregation area prior to fishing. Given these uncertainties, we cannot conclude whether the levels of fishing reported in 1997 and 1998 were sustainable.

3. The estimated biomass in 1999 was 211 tonnes, which was less than the 220 tonnes estimated for 1998, and less again than the total commercial catch of 235 tonnes taken in 1997. These numbers suggest a declining biomass, however, the decreases in biomass (4-6%) were relatively small with respect to the standard errors associated with the estimates (14-46%).

4. The methods of abundance and biomass estimation are based on numerous assumptions about the movement patterns of the animals at several spatial scales. It became apparent during 1999 that these assumptions may be invalid and the methods used may be underestimating the true biomass visiting the area over the course of the season.

5. Management considerations

The increases in surveyed abundance and biomass in the previously fished area in 1999 when fishing did not occur, demonstrate how vulnerable the spawning aggregation is to intense fishing effort for even short periods of time. In addition, individual licence holders have the potential to take very large catches, so limiting the number of licence holders alone, would be unlikely to reduce the overall catch. The best method of controlling fishing effort is likely to be through a continuation of the current policy of time and area closures, which ensure a large percentage of the spawning biomass is protected and allowed to spawn each year.

Due to the likely semelparous life history of the species (i.e. spawn once and die) there is unlikely to be any spawning stock carried over from one year to the next. Therefore, the biomass of the subsequent year largely depends on successful recruitment from the previous year (Rosenberg *et al.* 1990). Consequently, overfishing in one year could cause recruitment failure in the next, and thus have a detrimental effect on the persistence of the stock (Beddington *et al.* 1990).

Cuttlefish currently attract a low price, which means that large catches are required for economic viability. Although there may be opportunity to increase the unit value of the catch, due to the unique nature of the spawning aggregation there are other stakeholders who gain economic return from the aggregation not being fished. This is considered in more detail below in the section on market and economic considerations.

4.3. Market and economic considerations

Commercial fishery sector

The value of cuttlefish to commercial fishermen is quite low (average price of around $0.40 - $2.00 per kg) who need to achieve high catch rates (greater than around 700kg/day) to ensure sufficient economic benefit.

The low price received for cuttlefish in Australia is a reflection of the low domestic demand for the product and relatively low export price received by processors. If the profit margin of processors could be increased through better marketing, it might lead to higher returns for fishers.

Seafood processing and export sector

S. apama might fetch a higher export price if appropriate processing, packaging and markets were identified.

This species is one of the largest cuttlefish species in the world commonly ranging from 500g-3kg each whole weight and 200g-1kg each cleaned mantle weight. Larger cuttlefish species tend to fetch higher prices in all markets. Furthermore, the product is of very high quality, caught using hand lines and jigs as opposed to trawling, the method most commonly used in foreign cuttlefish fisheries. It can also be transported to Adelaide overnight for processing the following day, such that it could easily be kept and air-freighted fresh as opposed to frozen. Fresh whole and processed cuttlefish fetch a much higher price in Asian markets than frozen cuttlefish.

Due consideration needs to be given to the price fluctuations common in the Asian cephalopod markets. In 1998, one Adelaide processor recorded a loss of $0.80 per kg on a large shipment of cuttlefish due to a drop in price in Asian markets resulting from large supplies and economic decline in the region.

Cuttlefish prices in Asian markets tend to be influenced by trends in squid supply (Court 1999). Prices in Tokyo markets are generally higher in April and May prior to commencement of the main Japanese squid fishing season. They then drop during June and July as fresh squid flood the markets. An average price of ¥714 per kg (about AUS$10 per kg) for whole fresh cuttlefish was recorded at the Japanese Tsukiji Auction market (Tokyo) in May 1999 (Lin G. 1999, pers. comm.). Processed fresh cuttlefish fetched prices as high as ¥1,680 per kg (about AUS$24 per kg), depending on quality of processing and packaging.

A small workshop will be held in Adelaide in 2000 to discuss potential markets, processing preferences and value-adding options for the export of the South Australian cuttlefish product to Asian markets.

Recreational diving and tourism sector

Due to the unique nature of the spawning aggregation in the Black Point to Point Lowly region, interest in the aggregation as a recreational dive attraction and scientific research area has increased over the last three years. Nowhere else around the world is such a large spawning aggregation of cuttlefish known to occur. The cuttlefish are quite a spectacular sight while spawning, due to their impressive numbers and colourful mating displays. They are very accessible to divers of all standards, occurring over shallow inshore reefs in less than 8m of water. During the winter months, the site is relatively sheltered from prevailing weather conditions making for good dive conditions.

Considerable financial benefit from the recreational dive interest is being gained by local dive and tourism operators. Over 420 people visited the Whyalla region in 1999 in relation to recreational diving on the spawning aggregation (Bramley T. 1999, pers. comm.). Of those, 340 were divers who completed approximately 1,260 dives on the aggregation. The visitors contributed an estimated $55,000 to the local Whyalla economy (Bramley T. 1999, pers. comm.), through dive-related expenses, accommodation, travel and living expenses. A total of around 900 dives were also completed on the aggregation by local residents and dive club members with direct expenditure of about $12,000. In addition, two film crews visited Whyalla during the 1999 spawning season. One of them stayed for 6 months and expenditure for both film crews was about $36,000.

Further increases in visitors and interest in the spawning aggregation is expected next year with many bookings already confirmed including return visits by film crews and international scientists. There is strong support and interest from the local Whyalla community for a marine sanctuary to be established for the area during the spawning season. The dive site is being promoted through an internet web site "Cuttlefish Capital of the World", which has recorded 37,849 hits since its' launch in June 1999, many of them from overseas.

Obviously the attraction of the spawning aggregation as an eco-tourism site depends on high densities of cuttlefish. Significant reductions in numbers caused by overfishing would be unfavourable to these ventures.

Film and television sector

Interest in the site for wildlife film and photography has also increased over the last two years. Two film crews visited the area in 1999 and three in 1998, including the ABC, Australian Geographic and internationally renowned cinematographer David Hannon. Not only do these crews contribute to the local economy while in the region, they also promote awareness of the spawning aggregation through their documentaries and magazine articles, attracting more visitors to the local area.

Significant profit is also made by the film and television sector through sale of footage and photographs (see table 3d for details).

4.4. Environmental issues

Cuttlefish make up a significant proportion of the diets of Australian fur seals, sea lions and other marine animals (Gales *et al.* 1993). The specific role of the aggregation in the local foodweb of northern Spencer Gulf is not known but they have been observed to be preyed upon by dolphins, Port Jackson sharks, snapper and seabirds while in the region.

Likewise it is not known what contribution the spawning activity occurring at Black Point has towards the abundance of cuttlefish in other regions of South Australia where Australian fur seals, sea lions and other endangered or protected species may rely upon them for a food source.

Their depletion due to overfishing may therefore impact on some endangered or protected species and the local foodweb in general.

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