The life history and fishery of a spawning aggregation of the giant Australian cuttlefish *Sepia apama*

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Abstract

Every austral winter, thousands of giant Australian cuttlefish, *Sepia apama* Gray, 1849, aggregate to spawn over a small area of subtidal rocky reef in northern Spencer Gulf, South Australia, constituting the only known spawning aggregation of cuttlefish in the world. Rapid expansion of commercial fishing operations on the aggregation between 1994 and 1997 caused considerable concern for the sustainability of the population. However, determining an appropriate management strategy for the fishery was hampered by a paucity of biological information. Despite its large size and common occurrence, *S. apama* had previously attracted little scientific interest. Therefore, the general aim of this study was to provide some understanding of the life history of *S. apama* in the wider northern Spencer Gulf region and to relate this to the population dynamics at the aggregation area.

The dynamics of the spawning population were investigated using underwater visual transect methods from 1998 to 2001. Different time and area closures were implemented over this four-year period, allowing for comparisons between fished and unfished sites. Temporal trends in density indicated a distinct annual spawning season between May and August, with a consistent peak in early June. During the season densities as high as 85 cuttlefish.$100m^{-2}$ were recorded, whereas at other times they were less than 1 cuttlefish.$100m^{-2}$. Tagging work verified that individual cuttlefish remained at the aggregation area for a large part of the spawning season, such that it was valid to estimate total abundance and biomass at the time of peak numbers. In non-fished years total abundances reached over 170,000 individuals. Although biomass estimates indicated a decline in the total population size from 222 t in 1999 to 184 t in 2001, no long-term effects due to previous fishing could be concluded.

Cuttlefish were not evenly distributed amongst habitats or sites within the aggregation area, although the pattern of distribution was consistent between years. To this effect, the original closed area in 1998 represented 43% of the estimated hard substrate but only accounted for 19 to 28% of the total estimated biomass in each year. Therefore, the spatial distribution and movement patterns of cuttlefish within the aggregation area have important implications for the implementation of future area closures. At non-spawning times, cuttlefish were widely distributed throughout the northern Spencer Gulf at much lower densities than those recorded at the aggregation area. One cuttlefish tagged 65 km south of the aggregation area was later recaptured at the spawning site, suggesting that the aggregated population is drawn from that of the broader region.

There were multiple size classes within both the spawning and non-spawning populations of the Gulf, which suggested the presence of multiple year classes. The cuttlebones and other hard structures were examined as potential indicators of age. The width of growth increments in the cuttlebones varied seasonally over the length of the bone. The analysis of many bones indicated the existence of two year classes for each sex. They also suggested there were two alternative life cycle types in northern Spencer Gulf. The first was characterised by rapidly growing juveniles that attained maturity within 7 to 8 months, and which then returned to spawn as small adults in the first spawning season following hatching. The second life cycle type was characterised by slower growing juveniles that ultimately did not return to the aggregation area until the second year after hatching, and thus lived for nearly two years. Individuals conforming to the first life cycle type vastly outnumbered those of the second. Aquarium experiments using juveniles hatched and reared in captivity under different temperature and feeding regimes supported the above interpretation of the adult cuttlebone microstructures. Juveniles fed double rations achieved higher growth rates and had wider and more numerous growth increments in their bones than those fed half rations. The effect of temperature was confounded by the use of equal rations across temperature treatments rather than ad libitum feeding.

Reproductive indices confirmed that all individuals at the aggregation area, irrespective of size or age, were mature and spawning, whilst those in the wider Gulf population were immature and feeding. Gonad weight and gamete size were positively correlated with body size in both sexes; suggesting a difference in the reproductive potential of the two different year classes. There was a decline in condition during spawning, supporting the hypothesis of a semelparous spawning strategy. The sex composition of the spawning population was highly biased toward males, with 3 to 6 males per female, whilst the sex ratio of the northern Spencer Gulf population tended toward unity. No single explanation for this disparity could be determined. The mating system was described through analysis of the reproductive behaviours of spawning individuals from video recordings. Many behaviours related to sexual selection were displayed by individuals of both sexes, which were consistent with expectations that relate to the biased operational sex ratio. Large and small males, representing the different year classes, used different behavioural tactics to compete for females, but there was no assortative mating with respect to size. Therefore, the two year classes were not reproductively isolated. Various mechanisms for the determination of life cycle type were discussed with the most likely a cut-off conditional mechanism.