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Effects of culture density on growth and broodstock management of the cuttlefish, *Sepia officinalis* (Linnaeus, 1758)

Miguel Correia*, Pedro M. Domingues, António Sykes, José P. Andrade

CCMar, Universidade do Algarve. F.C.M.A., Campus de Gambelas, 8000-810 Faro, Portugal

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Abstract

The effects of culture density on growth and broodstock management of the cuttlefish *S. officinalis* were studied. Cuttlefish used were one month old at the start of the experiment, on average; two densities were used (16 and 76 cuttlefish m^{-2}). During the first experiment (until day 43), dead cuttlefish were replaced by individuals of similar weight. From that day onwards, no cuttlefish were replaced. No significant differences in growth and feeding rates, or food conversions were found between densities, during the first experiment. Results indicate that densities up to 76 cuttlefish m^{-2} are suitable for cuttlefish weighing approximately 10 g. After day 43 until first female layed eggs (second experiment), no statistical differences were found between densities for all the parameters studied with the exception of growth. In this case, cuttlefish cultured at the lower density grew more than those ones cultured at the higher density, with average weights at the start of egg laying of 137.3±21.6 and 91.8±12.3 g, respectively. This difference in growth could be explained mainly by the different culture densities and biomass associated.

Fecundity obtained for cuttlefish cultured at the lower density (834 eggs $female^{-1}$) was higher than for those ones cultured at the higher density (290 eggs $female^{-1}$), however fertility was higher for the higher density. These results were expected, since fecundity is directly related to the size of females. Significant differences were found in fertility (hatching percentage) between densities. Mean hatching percentage was of 35.8±9.4% and 62.0±16.9% for low and high density, respectively. This difference was unexpected since we expected eggs from females cultured at lower densities to have higher quality. Mean hatchling weight was of 0.079±0.011 and 0.072±0.012 g for low and high density respectively, and significantly different.

Results indicate that lower culture density promoted higher growth, larger eggs and hatchlings, but had no influence on juvenile and adult survival. On the contrary, eggs from females cultured at higher densities resulted in higher hatching rates.

Keywords: Culture density; Cuttlefish; Fecundity; Fertility; Growth; Life cycle

1. Introduction

Cephalopods have high growth rates (between 3% and 10% body weight per day (bw d^{-1}) on average)

* Corresponding author.
E-mail address: mtcorreia@ualg.pt (M. Correia).

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(Lee, 1994) which can be higher than 20% bw d^{-1} for the early stages of their life (O'Dor and Wells, 1987; Domingues et al., 2001a). They also have high food conversion rates (Domingues et al., 2003a,b), feeding rates between 20 and 50% bw d^{-1} (Boucher-Rodoni et al., 1987) and short life cycles (Forsythe and Van Hewkelem, 1987; Domingues et al., 2001a, 2002). The importance of cephalopod aquaculture has increased during the past few years (Lee et al., 1998), based on the recognized potential of some species for commercial aquaculture (Boucaud-Camou, 1990; Hanlon et al., 1991; Lee et al., 1998).

The European cuttlefish *Sepia officinalis* has been maintained, reared and cultured in the laboratory for many years (Boletzky, 1975; Richard, 1975; Pascual, 1978; Boletzky, 1979, 1983; Boletzky and Hanlon, 1983; Forsythe et al., 1991; Forsythe et al., 1994; Lee et al., 1991; Domingues et al., 2001b, 2002). According to Forsythe et al. (1994), this species is highly adaptable to life in captivity and has large eggs, high hatchling survival, sedentary behaviour, tolerates high culture densities with little or even no cannibalism, handling, shipping, accepts dead prey and most importantly, readily reproduces in captivity. These characteristics make this species highly suitable for large scale culture.

One of the key aspects of successful large scale culture is determining the optimum culture densities (Forsythe et al., 2002; Domingues et al., 2003a; Sykes, 2003; Sykes et al., 2003). For several species of fish, such as sea bass (*Dicentrarchus labrax*) or sea bream (*Sparus aurata*), optimum culture densities are well-known. Nevertheless, only a few density studies for *S. officinalis* have been conducted (Nabhitabhata, 1995; Forsythe et al., 1994, 2002; Domingues et al., 2003a; Sykes, 2003; Sykes et al., 2003). Furthermore, in these studies, scarce information on growth and effects of juvenile and adult culture density on reproduction and other aspects of the life cycle has been supplied. Young *S. officinalis* tolerates high stocking densities well (Forsythe et al., 1994; Domingues et al., 2003a; Sykes et al., 2003). Studies following larger individuals through the full life cycle are needed to optimize the culture of this species. In fact, this is essential for the establishment of correct broodstock management.

The objectives of the present research were to study the effects of a high and a low culture density in juvenile growth, feeding and food conversion; and to assess the effect of crowding on mortality, growth and reproduction (fertility and fecundity) of cuttlefish. Such information is essential to determine a good culture density that will enable the establishment of broodstock management guidelines.

2. Material and methods

Two experiments were conducted at the field station of the University of the Algarve (South Portugal), located in the Natural Park of the Ria Formosa, in a flow-through culture system that was composed of 6 fibreglass cylindrical tanks (1 m diameter, 40 cm water depth and 250 L of volume), described in Domingues et al. (2001b). Each tank had strong aeration, provided by an air stone and two airlifts. Water was pumped from the Ria Formosa lagoon and filtered before entering the tanks. Salinity varied between 36±1‰ and water flow was of 120 L h^{-1} per tank. Overall temperature during both experiment varied between 22±3 °C on average.

In both experiments densities tested were 16 and 76 cuttlefish m^{-2}, using 13 cuttlefish per tank in the lowest density while for the highest density, 60 cuttlefish were used in each tank.

The cuttlefish in each experiments replicates were weighed every two weeks and fed with live grass shrimp (*Palaemonetes varians*) until the first female from any density layed eggs. At this point, due to the lack of grass shrimp available, additional prey was supplied such as live crabs (*Carcinus maenas*) and fish (*Atherina* sp. and *Gobius* sp.) as complementation. Prey was captured daily in ponds surrounding the culture facility, using bottom hand held trawling nets. Feeding rates at the start of the experiment were set between 10% and 20% bw d^{-1}, which is considered to be a satisfying ration, according to Domingues et al. (2001a, 2002, 2003a,b, 2004). During the interval of weighing periods, food provided was adjusted by observation of the remaining prey in the tanks. After each weighing period and knowing the total biomass present in each tank, food rations were re-calculated, always above 10% bw d^{-1}. During the total duration of the experiment, cuttlefish were always fed ad libitum, as prey was always present in the tanks. Before each weighing period, all remaining prey in each tank was