Experimental harvesting of juvenile common octopus *Octopus vulgaris,* for commercial ongrowing in the Azores

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Octopus aquaculture is currently restricted to ongrowing of sub-adult to commercial size because culture of paralarvae remains a bottleneck. In most countries, commercial ongrowing rely upon existing pot fisheries for octopuses for obtaining their specimens. In the Azores, such fishery does not exist and effective methods of harvest are required if farming is to be implemented. In this study, we investigated the potential of obtaining sub-adult octopuses on the coast of Faial Island, Azores. Two sets of traps (n=30) consisting of 3 PVC tubes within cement blocks were set-up on two different substrates; soft sediment (Pedro Miguel) and rocky-sand (Pasteleiro) at depth varying between 10 and 30 metres. From June to August 2006, 11 hauls per site were performed. A total of 191 octopuses (from 1.1 to 989 g; average = 135.3 g) were captured. Catches in the soft sediment site were significantly higher than in the other location (CPUE: mean ± SD: 0.33 ± 0.17 vs. 0.15 ± 0.17 octopus $trap^{-1}$ $hour^{-1}$*100). The catch was initially dominated by octopus of 300-400 g but as fishing continued, this size classes disappeared and was replaced by smaller individuals. As a result, half of the catch at both sites (51.8%) was composed of specimens with a weight equal or inferior to 50 grams. The occurrence of summer recruitment event combined with a natural displacement of larger individuals into deeper waters is most probably responsible for this pattern. Our results showed that in shallow water and during this period of the year, individuals inferior to 50 grams are far more abundant than larger octopuses and should be the target size class for ongrowing activities.

Key words: aquaculture, catch, rocky-sediment, soft-sediment, traps, tubes

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INTRODUCTION

The contribution of aquaculture towards total seafood production is increasing rapidly, becoming a significant economic activity for many nations (Soto 2008). Throughout its wide distribution, the common octopus, *Octopus vulgaris* (Cuvier 1797) is a highly valued protein source (Hastie et al. 2009). In the Azores, *O. vulgaris* is harvested on a small scale (Carreira et al. 2002) and mariculture could represent locally an additional source of octopuses. Although cephalopods are increasingly being exploited, cephalopod mariculture remains poorly developed when compared to other molluscs (Boyle & Rodhouse 2005). For octopods, this can be attributed principally to the difficulty in rearing early life stages (Iglesias et al. 2007). Within the cephalopods, two general developmental strategies exists (reviewed by Boletzky 1981): (i) the production of a few large telolecithal eggs resulting in large, adult-like benthic hatchlings (e.g. cuttlefish and in some octopuses) and (ii) the production of a high number of small, less yolky eggs generating small planktonic juveniles (e.g. loliginids, sepiolids and octopuses), termed

paralarvae (Young & Harman 1988). *Octopus vulgaris* falls into the latter category, going through a planktonic stage of 20 to 35 days, depending on water temperature (Villanueva et al. 1995). Despite the high number of attributes for mariculture (e.g. fast growth, high fecundity, high food conversion ratio, etc.), large-scale farming of *O. vulgaris* has been strongly constrained by high mortality rates during the paralarval phase (Iglesias et al. 2007).

At present, the few companies producing octopuses are relying upon pot fisheries for obtaining sub-adults, subsequently grown in cages (Vaz-Pires et al. 2004). Although, in the Azores, such fisheries could be developed (Carreira & Gonçalves 2008), octopuses are currently caught mostly with spears by snorkelling divers with no by-catch of small individuals (Gonçalves et al. 2002). As a result, octopus farming could only be possible if a cheap and effective method of obtaining small specimens can be developed. Trap fishing for octopuses is successfully performed in many places (e.g. Portugal [Cunha & Moreno 1994]; Spain [Guerra 1981; 1997]; Canary Islands [Hérnandez-García et al. 1998]; California [Rasmussen 1997]). In the Azores, an experimental fishery using Japanese baited pots suggested that octopus of commercial size can be efficiently harvested and that CPUE is higher at shallowest depth (Carreira & Gonçalves 2008). The present study was conducted to evaluate whether small octopuses (300-400 g) could be harvested for commercial ongrowing using simple un-baited traps capable of capturing individuals of various sizes. We focused on maintaining a regular fishing pressure within two areas (of different substrate type) close to the harbour in shallow depths and assess their potential for octopus supply.

MATERIAL AND METHODS

The gear designed to harvest juvenile octopuses consisted of 30 cement traps (Fig. 1), placed 20 metres away from each other and buoyed at each end. Three PVC tubes of various diameters (70; 45 and 35 mm) were present on each trap and served as shelter for the octopus.

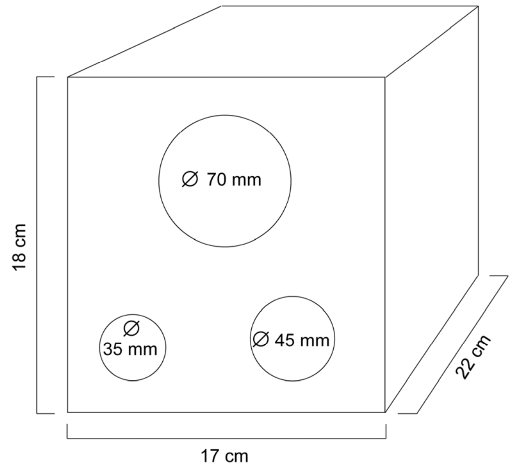

Fig. 1. Trap deployed to catch juvenile common octopus *O. vulgaris*, on the coast of Faial, Azores. PVC pipes of three different diameters were offered as shelter (70, 45 and 35 mm).

FISHING SITES

Harvesting effort (11 trips) was conducted between June and August 2006 in two sites on the coast of Faial, Azores. The first site (Pedro Miguel), is located on the east side of the island. At this location, the gear was systematically deployed on a soft sediment bottom, approximately 200 metres from a rocky shore, at a depth varying between 6 to 18 metres. The second site (Pasteleiro) is located on the south side of the island. Here, the gear was deployed on rocks yet with occasional small sandy patches (rocky-sand) at depths varying between 12 and 25 meters.

Across this location, practical problems arose because traps got caught amongst rocks and subsequently lost when hauled up (n=13). Traps were also lost in Pedro Miguel but less frequently (n=7). Gear soaking time was constrained by weather conditions and varied from 4 to 17 days. Soaking time for each trip was the same among sites.

BIOLOGICAL SAMPLING

Each trap was brought onboard and whenever an octopus was present, the position of the tube and trap number were recorded. Each octopus was placed into separate closed containers lowered into a tank previously filled with seawater. On arrival to the laboratory, each octopus was then

anaesthetised with a solution of MgCl (7.5%) diluted in seawater (1:1 ratio) (Messenger et al. 1985). This method was successful since it never resulted in mortality and allowed good manipulation of the animals. Each animal was weighed (total weight, TW, 0.1 g) and its mantle measured (dorsal mantle length, DML, 0.1 mm). The sex was determined in each specimen through the examination of the third right arm, which is shorter in males, with a round suckerless tip (hectocotylus), and usually presents a number of enlarged suckers when the octopus is fully mature. Growth rates were subsequently monitored in the laboratory using the same anaesthetic (Pham & Isidro 2009).

DATA ANALYSIS

For all fishing trips, the following indices were calculated:

1. Catch rate (defined as the number of octopus caught per number of pots):

(no. of octopuses / no. of traps) x 100

2. The catch per unit effort:

(Total Number of Octopus / n° of traps) x 100

For comparing two samples, a two sample t-test was performed since all assumptions were constantly met (normality and homogeneity of variances). Normality was tested using Anderson-Darling normality test whilst homogeneity of variances was estimated by performing a Levene's test (Zar 1996). Sex ratio was analyzed and differences tested using the Chi-square test. All statistical analyses were done with Minitab version 13.0 software (*Minitab Inc*).

RESULTS

SITE DIFFERENCE AND CATCH COMPOSITION

Over the 3 months period, a total of 191 octopuses (ranging from 1 to 989 g, TW) were caught. A summary of the catches at both sites is presented in Table 1. The number of octopuses caught in soft sediments (Pedro Miguel) was twice the amount captured at the rocky-sand site (Pasteleiro) and the mean CPUE in soft sediment was significantly different from the rocky-sand ($t = 2.36$; $p<0.05$). In the rocky-sand location, the CPUE was far more variable, when compared to the soft sediments.

The weight frequency of the octopuses caught at both sites is presented Figure 2. In total, half of the octopuses caught weighted less than 50 g. Sex ratio was not significantly different from 1:1 for both areas ($P>0.05$).

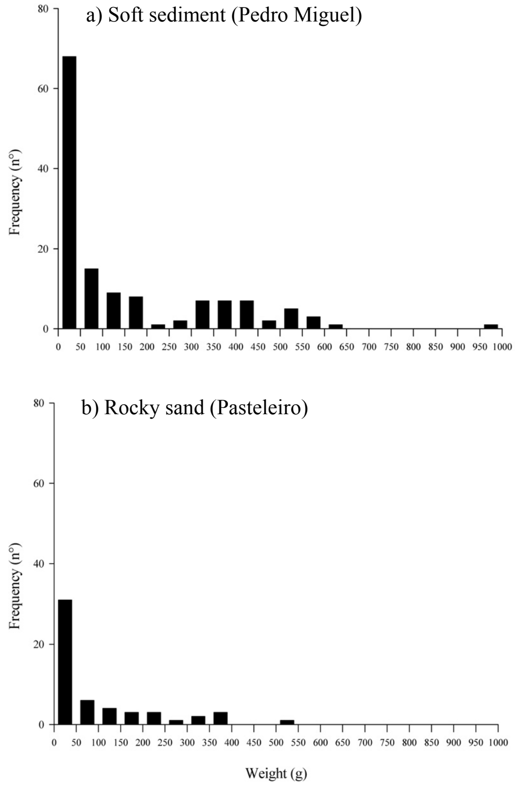

Fig. 2. Weight (g) frequency of common octopus *Octopus vulgaris*, caught at two different sites: a.) Soft sediment (Pedro Miguel) and b.) Rocky-sand (Pasteleiro).

In Pedro Miguel (soft sediment), there was a decrease in mean octopus weight with number of fishing trip (Pearson correlation coefficient = -0.305; $p<0.05$). In June, catches were dominated by octopuses larger than 150 g whereas in July and August, larger octopuses became scarce and the bulk of the catch was dominated by specimens

Table 1. Summary of the experimental harvesting of the common octopus *O. vulgaris,* on soft sediment (Pedro Miguel) and rocky-sand (Pasteleiro), around Faial Island, Azores, during summer 2006: mean values, standard deviation and min-max values are indicated.

	Soft Sediment	Min-Max	**Rocky-Sand**	Min-Max
Nº of trips / Total nº octopuses	11 / 136	-	11 / 55	-
N° of octopus 30 $traps^{-1}$	12 ± 1	*8 – 19*	5 ± 4.4	*0 – 14*
Octopus Total Weight (g)	150.1 ± 186.03	*1.1 – 989*	98 ± 124.7	*4.6 – 542.7*
CPUE (nº octopus $trap^{-1}$ $hour^{-1}$*100)	0.33 ± 0.17	*0.1 – 0.67*	0.15 ± 0.17	*0 – 0.43*
Catch rates (%)	48.3 ± 15.3	*27.6 – 73*	20.7 ± 17.3	*0 – 51.8*

smaller than 150 grams. The situation was rather different at the other location, probably because the gear position was regularly changed between fishing trips. This resulted in little pattern as catch composition varied enormously.

RELATIONSHIP BETWEEN SOAKING TIME & CATCH

Due to unfavourable weather conditions, gear soaking time could not remain consistent for each trip and varied between 4 to 17 days. There was no significant correlation between CPUE and soaking time (Pearson correlation coefficient = -0.205; $p>0.05$).

TUBE DIAMETER SELECTIVITY

One trap never caught more than one individual. Table 2 displays the mean, minimum and maximum weights (TW) of the octopuses caught by the three different tubes. The largest tube (Ǿ 70 mm) caught the highest number of individuals, representing approximately 50% of the total catch. The two other small tubes (35 mm and 45 mm) caught the rest of the octopuses in equal proportions (25% each tubes). Whilst small tubes were highly size-selective, most exclusively catching small octopuses (1.1 to 198 g), the 70 mm tube caught both large and small individuals, ranging from 7 to 900 g (Fig. 3a).

Table 2. Mean total weight (TW, grams), standard deviations (SD), minimum (min) and maximum (max) weights and associated number (N) of octopuses caught in PVC tubes of different diameters (mm).

Tube Ǿ	Mean TW	SD	Min-Max	N
35	20.54	17.5	1.1 – 82.9	44
45	34.23	34.26	5 – 198	45
70	232.51	188.98	7.6 – 989	102

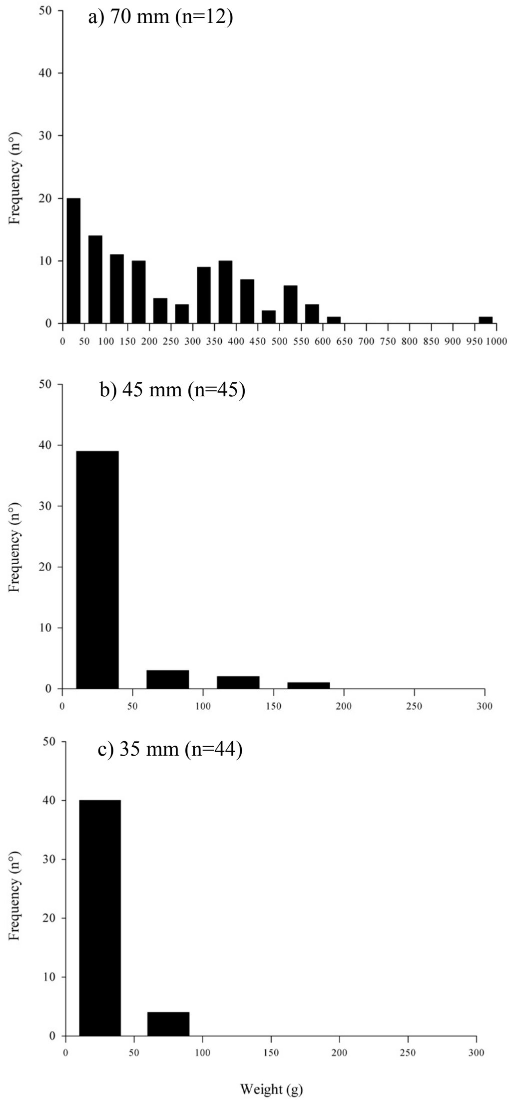

Fig. 3. Weight (g) frequency of octopuses caught in a) 70 mm tube, b) 45 mm tube and c) 35 mm tube for both sites joined together.

DISCUSSION

The mariculture of *O. vulgaris* for commercial purposes has been limited to the ongrowing of sub-adults (e.g. Chapela et al. 2006; Rodriguez et al. 2006), implying the need for a reliable method of obtaining undersize animals directly from the field. The results of the present study provide information on what to take into account if such activity is to be developed in the Azores. The gear used presented a satisfactory catching efficiency because the CPUEs obtained were similar to those previously obtained with Japanese baited pots for similar depth in the Azores (Carreira & Gonçalves 2008).

Octopus catches in soft sediment were significantly higher than in the rocky-sand zone. In shallow water, *O. vulgaris* is mostly inhabitant of coral reefs and rocks (Mangold 1983) but the large amount of natural dens available in such areas, makes traps ineffective for catching octopuses even though their abundance is high. In contrast, in soft sediments, den availability is a limiting factor (Katsanevakis & Verriopoulos 2004b) and enrichment experiments using artificial dens increase octopus abundance (Katsanevakis & Verriopoulos 2004a). As a result, trap fishing is more efficient on soft sediment than on rocky shores. Furthermore, gear operation over soft sediment is more convenient since fewer traps get caught up in rocks when hauled up.

Overall, the size composition in our catch showed a large dispersion (1.1 to 989 g) but was predominantly composed of small individuals (<150g). In fact, the proportion of small octopuses gradually increased throughout the summer. Similar to *O. vulgaris* found elsewhere (Guerra 1977; Hernández-García et al. 2002; Katsanevakis and Verriopoulos 2004a), in the Azores, the species spawns principally in spring (Gonçalves et al. 2002). After an embryonic period of 125 to 22 days (at 13 and 25°C, respectively; Mangold 1983) and a paralarval planktonic stage of 33-40 days (at 25°C), individuals assume a benthic existence and recruit into the population (Itami et al. 1963; Villanueva 1995). Thus, it is clear that the appearance of small individuals (10 – 50 g) in our late summer catches reflects the spring spawning event. This is in agreement with a previous study showing that despite recruitment occurring all year round, small animals are more abundant by the end of the summer (Gonçalves 1993).

The observed gradual disappearance of larger octopuses on the other hand, can be attributed to a natural displacement of larger individuals rather than a depletion effect of our harvesting activity. Medium and large octopuses are known to disappear from shallow waters from July onwards (Katsanevakis & Verriopoulos 2004b). During such period, when the thermocline is well pronounced, large octopuses seek cooler areas in deeper waters, to reduce the energy cost of higher metabolism whilst smaller octopuses remain in shallow warmer waters to achieve greater growth rates and reduce predation risks (Sánchez & Obarti 1993; Katsanevakis & Verriopoulos 2004b). Although our data suggests that such phenomenon might happen in the Azores, more research needs to be conducted as it has important implications for harvesting and fishing activities.

CONCLUSIONS

The results of this study highlighted important aspects to consider if ongrowing of wild octopuses should be implemented in the Azores. Firstly, specimen harvesting should strictly be undertaken over a soft sediment type substratum, preferably in the vicinity of a rocky shore. Secondly, considering the rapid disappearance of >150 g individuals and the dominance of smaller octopuses in the summer, commercial culture should aim at growing animals smaller than 150 g. Thirdly, soaking time should not exceed four days as longer time do not increase CPUE.

To be economically viable, a commercial aquaculture would require a much higher number of octopuses than the amount reported in this study but also within a shorter time frame. It is worth performing such experiments during other periods of the year where natural displacements of animals can be taken into account. Further work should not solely concentrate on the ecological implications of such activity but also on its economic feasibility.

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