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Growth of common octopus (*Octopus vulgaris*) in cages suspended from rafts*

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SUMMARY: Two ongrowing experiments were conducted using a raft deployed for rearing mussels during summer and winter in the Ria of Vigo, Galicia, NW Spain. Two 3 m x 1.5 m x 6 m galvanized iron ongrowing cages were suspended from this platform, each equipped with dens constructed from PVC pipe. Small common octopus (*Octopus vulgaris*) were captured by the small-scale creel fishery in the ria and placed in one of two sex-specific experimental cages. Specimens were fed a standard diet (fish, decapod crustacean and mussels) at a daily feeding rate of 5% of the total weight of the animals in each cage. Due to the very high mortality as a result of decreased salinity in the winter experiment and spawning during the summer experiment, only data from the first 75 days of each experiment were compared. Growth rates were significantly higher in summer than in winter for both sexes, which was probably due to higher ambient culture temperatures during summer. Mortality was also higher during summer than winter. It was concluded that culture of common octopus on mussel rafts may be viable, especially if problems related to salinity, the acquisition of specimens from the wild and losses due to spawning can be reduced.

Keywords: *Octopus vulgaris*, growth, ongrowing, NW Spain.

RESUMEN: CRECIMIENTO DE PULPO COMÚN (*OCTOPUS VULGARIS*) EN JAULAS FLOTANTES. – En este estudio se realizaron dos experimentos de engorde de pulpo común (*Octopus vulgaris*) en jaulas suspendidas desde una plataforma de cultivo de mejillón en la Ría de Vigo (Galicia, noroeste de España). Las dimensiones de cada jaula de hierro galvanizado fueron 3 x 1,5 x 6 m, y cada una de ellas estaba equipada con cobijos de PVC. Los pulpos de pequeño tamaño se obtuvieron en la pesquería de la Ría de Vigo y se introdujeron por separado, machos y hembras, en cada una de ellas. Los ejemplares fueron alimentados con una tasa de alimento del 5% del peso medio de los animales de cada jaula con una dieta estándar compuesta por peces, crustáceos decápodos y mejillón. Únicamente se utilizaron los datos de los 75 primeros días de cada experimento debido a la elevada mortalidad de los animales al final del experimento de inverno por descenso brusco de la salinidad y al desove de los animales de verano. Las tasas de crecimiento de ambos sexos fueron significativamente más altas en verano que en invierno posiblemente debido a las mayores temperaturas ambientales durante el estío. La mortalidad fue más elevada en verano que en invierno. Esta experiencia indicó que el engorde de pulpo en jaulas sería viable, especialmente si los problemas debidos al descenso de la salinidad, la obtención de ejemplares de la naturaleza y al desove de las hembras pueden reducirse.

Palabras clave: *Octopus vulgaris*, crecimiento, engorde, NO España.

INTRODUCTION

Spanish imports of fresh and frozen octopuses, mainly the common octopus (*Octopus vulgaris*), reached 30,404 t in 2000, while exports totalled 27,190 t (FAO, 2002). The increasing demand and market value of this species in the Spanish market has resulted in increased interest in culturing it. The fishing sector in Galicia (NW Spain) demands increased diversification of the mariculture industry, which is currently based mainly on the culture of

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mussels (*Mytilus galloprovincialis*) suspended from rafts located in the Galician Rias and of turbot (*Scophthalmus maximus*) in tanks situated on shore. The common octopus has been identified as an important potential candidate for mariculture (Iglesias *et al.,* 1996), because adults have suitable characteristics for being reared (Mangold and Boletzky, 1973; Boletzky and Hanlon, 1987; García-Allut and Aguado, 2002). However, the main problem with cultures of this species is related to failure in rearing paralarvae (Navarro and Villanueva, 2003). Among other reasons, this could be because a commercial diet is not available, as the early stages of development require live prey.

Small-scale common octopus fishery in Galicia has yielded 2268-3675 t annually during the past seven years (www.pescagalicia.com). The minimum legal weight of landed individuals is 750 g. Interest in ongrowing of common octopus in Galicia is related to the higher market value of animals weighing more than 2 kg compared with smaller specimens. We observed that the availability of specimens larger then 2 kg had declined in the decade before 2003, when the fishery was closed for six months due to the oil spill produced by the vessel *Prestige*. Therefore, the ongrowing of animals smaller than 2 kg would increase their market value and regulate the supply of large animals. Ongrowing in floating cages in Atlantic European waters first commenced in the Ria of Camariñas (North Galicia), while the experiments in tanks started in North Portugal, in early 1995 (Guerra and González, unpub. data; Sendâo-Silva, 1997; Luaces and Rey-Mendez, 1999). Afterwards, other tank experiments were carried out by Iglesias *et al.* (1996, 1997, 2000, 2004), and Sánchez *et al.* (1998). Rama-Villar *et al.* (1997) give the first results of ongrowing in cages situated in the Ria of Muros (West Galicia). Later, a two year ongrowing trial in cages was undertaken in the Ria of Aldán (Southwest Galicia), which was used as the main antecedents for the trials presented in this paper (Hebberecht, pers. comm.). These trials, based on the ongrowing of immature common octopus captured in the Galician fishery (Iglesias *et al.,* 2000), provided a total of 104 t during 1997-2000 with a market value of 517,800 € or US$ 640,000 (Fernández-Otero, 1999; Rodriguez-González, pers. comm.). The main results of the studies undertaken using rafts could be summarized as follows: a) the lower limit of salinity should be 30 psu; b) feeding should be provided *ad libitum* of a varying diet constituted by fish, crustacean and molluscs; c) the daily feeding ratio should be about 5% of the average weight of the animals; d) feeding should be done once a day; e) if possible, similar sized animals should be introduced simultaneously into each cage; f) males and females should be separated in different cages; g) dens should be provided in 20% excess; h) initial density should range from 8 to 14 Kg m^{-3}; i) the growth rates differed considerably due to the heterogeneity conditions of the ongrowing but in general the authors obtained growth rates (G) ranging from 0.66 to 2.11 g d^{-1} and from 0.36 to 2.0 g d^{-1} for males and females respectively, at temperatures of 12-19ºC; j) mortality rates varied from 3 to 35% depending on several factors such as initial weight, days of culture, temperature, season, density, type of cage, etc.

The rafts used for the commercial culture of mussels represent promising platforms for ongrowing experiments, although ultimate success will depend on several factors, including environmental conditions, diet, the design of cages and dens, and animal density. The purpose of this study was to estimate growth rates of common octopus during ongrowing trials using cages suspended from rafts. Our experiments were directed more specifically towards determining the effects of sex and season on growth rate and mortality so as to evaluate whether ongrowing octopus on mussel rafts is commercially viable.

MATERIALS AND METHODS

Ongrowing trials were carried out from a raft used in Galicia for mussel-culture in 2000. The raft (Fig. 1) was situated in the northern part of the Ría of Vigo (NW Spain) at the following coordinates: 42º16.31N-08º43.53W. Two galvanized iron cages of 20 mm mesh size, suspended from this platform, were used for the present study (Fig. 1). The dimensions of each cage (Fig. 2) were 3 m in length, 1.5 m in width and 6 m in height. The dens used in each cage (Fig. 2) were T-shaped tubes of 16 cm-diameter PVC pipe. Each (sex-specific) experimental cage contained 255 PVC tubes with a 16 cm diameter (Fig. 2). These dens were placed at depths ranging from 1.5 to 5.5 m.

Two ongrowing trials were carried out; one in winter (Trial 1) and another in summer (Trial 2).

Trial 1: Animals were acquired and placed in cages over the period 24 January to 11 February, 2000 due to irregular supplies from the fishery. To calculate the ongrowing period we used 1 February,

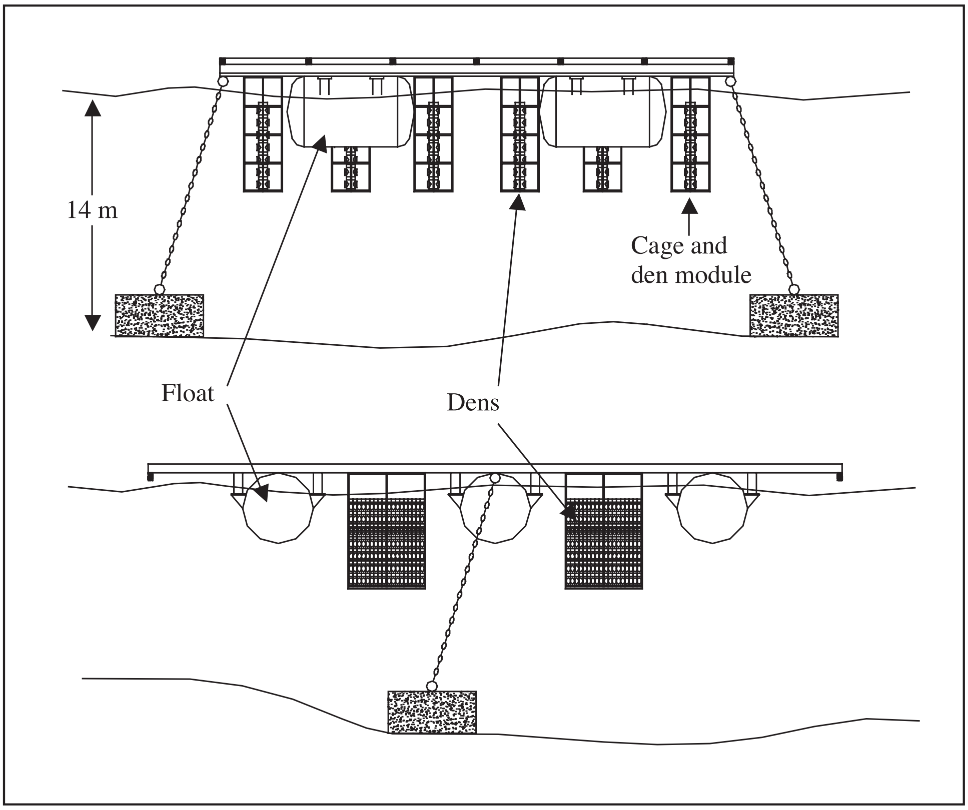

FIG. 1. – Diagram of the side (above) and end (below) views of the culture platform and cages.

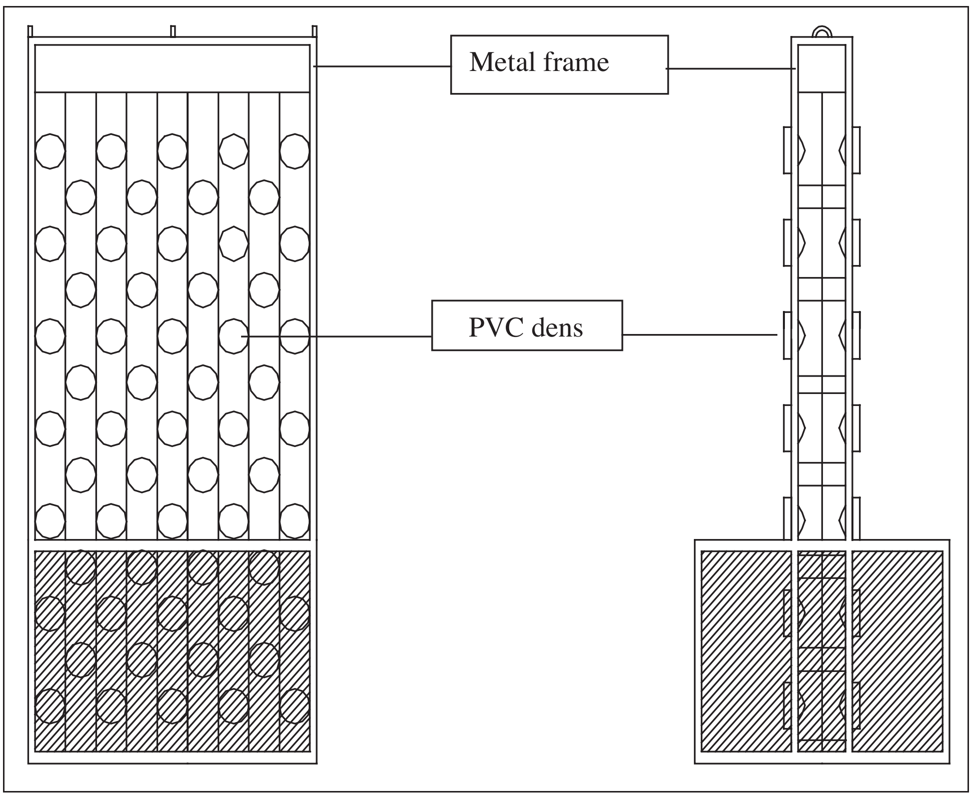

FIG. 2. – Diagram of the side (right) and end (left) views of a den module. The screened section of the module is an external cage to collect the octopus that try to escape when the modules are removed from the cage.

2000 as the starting date. This experiment ended on 10 May, 2000 encompassing a period of 99 days. The two sex-specific experimental cages contained 204 males and 174 females at the start of the trial.

Trial 2: Specimens were acquired and placed in cages over the period 22 to 29 May 2000; May 25 was used as the starting date of the trial. The sex-specific experimental cages contained 229 males and 222 females at the start of the experiment. This trial ended on 16 and 23 August, 2000 for males and females respectively, comprising respective periods of 83 and 90 days.

Experimental specimens were captured by small-scale creel fishing in the Ria of Vigo. Each specimen was transported to the raft in a PVC tube (10 cm in diameter and 20 cm in length), that was covered at both ends with nylon netting. These tubes were submerged in tanks with an open seawater circulation system aboard the fishing vessel during the two-hour transit to the raft. Each animal was weighed to the nearest g before being placed in a cage, removing the water from the mantle cavity as much as possible and drying it with filter paper trying to cause the minimum stress to the animal.

Food was bought fresh or frozen from local bait suppliers and stored in freezers at -20ºC. The diet supplied every day was consistent throughout the trials and consisted of 68% fish (30% *Scomber scombrus*, 18% *Micromesistius poutassou*, 9% *Boops boops*, 9% *Trachurus trachurus* and 2% *Sardina pilchardus*), 18% decapod crustacean (*Polybius henslowii*) and 14% mussels (*Mytilus galloprovincialis*). The daily feeding rate was 5% of the total weight of the animals in each cage and thus varied as a function of the weight of the animals throughout the trial. Feeding was undertaken daily from 10:00 to 12:00 h. Food was thawed and introduced intermittently into the upper part of each cage, so as to provide the octopus at each level the opportunity of capturing food as it sank.

A sample of 30 animals of each sex was collected on day 30 and day 75 from outside the dens of each sex-specific cage by SCUBA diving. These animals were chosen randomly, weighed as previously described, and then returned to the cages. Cages were cleaned of fouling organisms and dead octopuses were removed during these sampling operations. Food remains were removed daily with the aid of a vacuum.

After each trial, we recorded the total number of egg masses in the dens and number of strings per egg mass, as well as the live weight of the corresponding female. Furthermore, each egg mass was weighed and a subsample (10% of the total weight) was collected for estimation of fecundity. The total number of eggs in each mass was obtained by extrapolation from the eggs counted in the subsample. Finally, we obtained the correlation between the female live weight and the number of eggs.

Instantaneous relative growth rate was calculated according to Forsythe and Van Heukelem (1987) as:

$$G = 100\,(\ln BW_2 - \ln BW_1) / (t_2 - t_1),$$

where BW is the live body weight in g at time t in days.

We also estimated absolute growth rate as:

$$AGR = (BW_2 - BW_1) / (t_2 - t_1),$$

BW_1 and BW_2 are mean weights of the 30 randomly selected animals. The G and AGR for a given animal could not be estimated because they were not tagged and thus the dispersion of G and AGR could not be calculated because we do not have replicas for that given animal.

Mortality rate was estimated as:

$$MR = 100 - (100\,N_f/N_i),$$

where N_f and N_i are the final and initial number of animals respectively.

The significance of differences in mean body weight between the season-specific experiments according to sex was determined using the Student's t-test (Zar, 1999).

Temperature and salinity data were obtained from two different sources. Data for 0-20 m depths, at the coordinates 42º16'N 08º43'W, were obtained from the Quality Control Centre of Galician Waters. In addition, daily in situ measurements were derived throughout the experiments at 0 m, 3 m and 6 m depths, as well as at additional depths of 2, 3, 4 and 5 m from 19 to 27 April, a period of unusually heavy rainfall. This heavy rainfall substantially increased the input of fresh water into the inner part of the Ria of Vigo from the rivers Oitavén and Verdugo.

RESULTS

Results of the winter and summer experiments are presented in Table 1 for the days 0, 30 and 75. We only used the data from the first three quarters

TABLE 1. – Seasonal growth comparison. Temperature was 13.4 ± 1.2 and 14.2 ± 1.4ºC for the first 30 days and the last 45 d of culture respectively in winter. Temperature was 16.2 ± 1.3 and 16.5 ± 1.7ºC for the first 30 days and the last 45 d of culture respectively in summer. Salinity ranged from 34.0 to 35.0 psu in winter and summer during the 75 days of culture.

Day/Sex	Day 0		Day 30		Day 75	
	Winter	Summer	Winter	Summer	Winter	Summer
Males						
Number of specimens	204	229	184	201	172	163
Mean Weight (Kg)	0.92	0.79	1.21	1.33	2.03	2.43
Standard Deviation	0.12	0.18	0.11	0.32	0.36	0.83
G (w, in g day^{-1})	-_	_	0.91	1.73	1.15	1.34
AGR (kg day^{-1})	_	_	0.010	0.018	0.018	0.024
MR%	_	_	9.8	12.2	6.5	18.9
t (Mean wt)	3.177		1.969		2.423	
p	$p<0.05$		$p>0.05$		$p<0.05$	
Females						
Number of specimens	174	222	162	191	153	145
Mean Weight (Kg)	0.92	0.81	1.16	1.60	1.92	2.44
Standard Deviation	0.13	0.17	0.16	0.43	0.27	0.59
G (w, in g day^{-1})	_	_	1.11	2.27	0.94	0.93
AGR (kg day^{-1})	_	_	0.008	0.026	0.017	0.019
MR%	_	_	6.9	13.8	5.6	24.1
t (Mean wt)	2.685		5.196		4.343	
p	$p<0.05$		$p<0.05$		$p<0.05$	

(75 days) of each trial to compare growth performance between seasons (trials), so as to eliminate the late effects of high mortality in the winter trial (Table 2) due to a sudden decrease in salinity (Tables 3) and of spawning in the summer trial (Table 4). Ambient water temperature for days 0-75 was higher in summer than winter (Table 1). It increased slightly between the first period (day 0-30) and the second period (day 31-75) in winter (13.4 and 14.2ºC respectively), whereas it changed little between these consecutive periods in the summer trial (16.2 and 16.5ºC respectively).

Growth performance during the summer experiment was superior to that during the winter trial for both sexes (Table 1). For males, the initial mean weight was significantly greater in winter than in summer (Table 1), but there was no significant difference at day 30; at day 75, the mean weight was significantly greater in summer than in winter. The mean weight of females was also initially greater in winter than in summer, but by day 30 the reverse was true, with females being significantly heavier in summer than in winter.

The superior growth performance in summer, especially in females, is reflected in seasonal differences in growth rate estimates (Table 1). The relative instantaneous growth rate (G) of males to day 30 in summer (1.73) was almost double that in winter (0.91), whereas the summer rate for females to day 30 (2.27) was more than double that in winter (1.11). The relative instantaneous growth rate for males during the second period (day 31-75) was again higher in summer (1.34) than in winter (1.15), whereas for females there was no seasonal difference (0.93 and 0.94).

TABLE 2. – Seasonal growth comparison from 75 d of culture onwards. Temperature was 14.3±1.4 and 16.5±1.7ºC in winter and summer respectively. Salinity ranged from 7.0 to 35.0 in winter and from 34.0 to 34.5 in summer

	Day 75 onwards	
	Winter	Summer
Males		
Initial Number of specimens	172	163
Initial Mean Weight (Kg)	2.03	2.43
Standard Deviation	0.36	0.83
Final mean weight	2.43	2.43
SD	0.55	0.56
G (w, in g day^{-1})	0.75	0
AGR (kg day^{-1})	0.016	0
Final number of specimens	52	163
MR	69.8	0
Days of culture	24	8
Temperature range	14.3±1.4	16.5±1.7
Salinity (psu)	7.0-35.0	34-34.5
Females		
Initial Number of specimens	153	145
Initial Mean Weight (Kg)	1.92	2.44
Standard Deviation	0.27	0.59
Final mean weight	2.26	2.21
SD	0.52	0.69
G (w, in g day^{-1})	0.68	-0.66
AGR (kg day^{-1})	0.014	-0.015
Final number of specimens	65	142
MR	57.5	2.0
Days of culture	24	15
Temperature range	14.3±1.4	16.5±1.7
Salinity (psu)	7.0-35.0	34-34.5

The absolute growth rate (AGR) to day 30 was higher in summer than in winter for both sexes, ranging from 0.01 kg d^{-1} for winter males to 0.026 kg d^{-1} for summer females. Growth, in absolute terms

TABLE 3. – Salinity (psu) and temperature (ºC, in parentheses) data from 19 to 27 April.

Date/depth(m)	0	1	2	3	4	5	6
April 19	34(13.6)	-	-	35(13.6)	-	-	35 (13.5)
April, 20	29(13.6)	30(13.6)	31(13.6)	33(13.6)	-	-	34(13.6)
April, 22	19(13.2)	24(13.7)	31(13.8)	34(13.8)	-	-	34 (13.7)
April, 24	20(13.6)	20(13.6)	22(13.7)	28(13.9)	-	-	-
April, 25	21(14.2)	21(14.2)	21(14.2)	21(14.2)	25(14.1)	30(14.0)	-
April, 26	14(12.8)	16(13.6)	27(14.0)	29(14.1)	-	-	32(13.9)
April, 27	7 (13.8)	25(14.5)	28(14.2)	30(14.0)	31.5(13.9)	31(13.9)	31(13.8)

was less variable from day 31 to 75, than during the early period, and was higher for summer males (0.024 kg d^{-1}) than for the other groups (0.017-0.019 kg d^{-1}). Whereas both relative and absolute growth rates were higher for females than males during the first 30 days of the trials, the reverse was true for days 30-75, with both G and AGR higher for males than for females. The relative growth rate decreased in both sexes during the second period of the summer trial (Table 1). AGR decreased by 35% in the second period for summer females.

Sex–specific mortality rates during the first 75 days of the experiments (Table 1) were lower during winter (5.6-9.8 %) than during summer (12.2-24.1 %). Mortality in summer was higher during the second period (day 31-75) than during the first period in both sexes, but especially in females, almost doubling between the two consecutive periods. Mortality after day 75 increased sharply in winter to 69.8% in males and 57.5% in females (Table 2). This sharp increase in mortality coincided with a substantial decrease in salinity within the upper 4 m of the water column (Table 3) from 20 to 27 April, 2000, a period of unusually heavy rainfall, which increased the input of freshwater from the rivers Oitavén and Verdugo that run into the inner part of the Ria of Vigo.

The mean weight of summer females was greater at day 75 than at the end of the experiment (Table 2). This decrease in mean weight was associated with spawning by 85 (60%) of the experimental females (Table 4). The mean number of eggs per gram of female at the end of the summer experiment was around 58. The ratio of the summer females' final mean weight to mean egg mass weight was 6:1, which indicates that about 17% of the female total weight was lost in spawning. Only 2 (3%) of the experimental females spawned during the winter experiment.

TABLE 4. – Spawning data from the summer experiment.

Spawning females (%)	60.0
Number of spawns	85
Period	May - August
Mean weight of post-spawning females (g)	1739.43±567.55
Mean Weight of spawning (g)	292.46±194.14
Average string number	64±16
Average number of eggs/spawn	101,010±5761
Mean number of eggs /string	91±23
Temperature range (°C)	16.0 - 20.0

DISCUSSION

We found significantly higher growth rates in summer than in winter for both sexes, probably due to higher temperatures during summer. This agrees with other studies that have shown that *O. vulgaris* growth rates increase with culture temperature (Nixon, 1966; Mangold and Boletzky, 1973; Mangold and Boucher-Rodoni, 1973; Smale and Buchan, 1981).

It is difficult to directly compare growth rates from our experiments with those from other studies, whether in the wild or in captivity, because of the confounding effects of temperature and body size. The form of growth in *O. vulgaris* changes from exponential to logistic at about 0.2 kg BW (Mangold and Boletzky 1973), so that instantaneous relative growth rates (G) decrease, while absolute growth rates (AGR) increase as size increases. The G estimated in our study is similar to those estimated by Sánchez *et al*. (1998), and Sendao (1999), in tanks at temperatures ranging from 12 to 19º C. However, in a previous trial we carried out using rafts (unpub. data) we obtained a G of 1.08 and 0.99 in a temperature range of 14-17ºC during 150 days, using 160 males and 162 females.

The instantaneous relative growth rates observed by Nixon (1966) were much higher than those from our experiments, ranging between 3.65 and 4.47 for specimens of 0.06-0.17 kg body weight within a temperature range of 14-27ºC. Nixon noted that G decreased abruptly from those high values to a range of only 1.26-0.45 in specimens larger than 0.17 kg.

Mangold and Boletzky (1973) also observed a sudden decrease of G from 4.79 to 1.76 between growth phases at 12-15ºC. The G calculated from the original data of Smale and Buchan (1981), in *O. vulgaris* culture experiments at 20-25ºC were highly variable and different for males and females (0.57 to 2.23 and 1.21 to 3.42 respectively). However, the mean values of G in these experiments (1.27 and 2.27 for males and females respectively) were similar to those obtained in the first 30 days of our summer experiment. This similarity, especially for females, was in spite of the higher culture temperature and smaller initial size (0.45 and 0.33 kg for males and females respectively) in the experiment of Smale and Buchan (1981) compared to our experiment, which points to the superior growth performance in our experiment. Smale and Buchan (1981) found absolute growth rates of 0.011 kg d^{-1} and 0.017 kg d^{-1} for males and females respectively, which were lower than those we obtained during our winter and summer experiments.

The G values in the first 30 days of our summer experiment were higher than those estimated by Domain *et al.* (2000), despite the smaller initial size (0.03-0.35 kg) and higher culture temperature (21-27ºC) in their experiment. Furthermore, our G values (0.91-2.27) were generally higher than those reported by Domain *et al.* (2000) in the wild in Senegalese waters for 0.25-2.9 kg common octopus both in the warm season (0.8-1.05) and the cold season (1.2-1.5). These higher growth rates in our two seasonal experiments, compared with those reported in the wild, despite the lower temperatures in our experiment, suggest that the culture conditions used promoted growth. These favourable conditions include an adequate food supply that reduces energetic costs of foraging, as well as a specially-designed diet.

We feel that the feeding rate we provided (5% of the average weight of the animals), resulted in feeding to near satiation, but not to excess. Mangold and Boletzky (1973) indicated that the mean relative food intake ranged from 4.2 to 6.6% at 20ºC, 2.3 to 4.5% at 15ºC and 1.4 to 1.7% at 10ºC. The food remains collected daily were almost totally comprised of prey hard parts, suggesting that feeding was not excessive. The experimental diet we selected was high in protein compared to lipids because lipid digestibility by cephalopods is low (O'Dor and Webber, 1986), and their capacity to catabolize lipids is very limited (Navarro and Villanueva, 2003). According to O'Dor and Webber (1986) proteins represent the main energy source for cephalopods.

The number of egg masses observed in the winter study was low, while 60% of the females reared during the summer spawned in the dens. This is consistent with the known late-spring and summer spawning season in the wild in Galician waters. Spawning during our summer experiment resulted in females losing 17% of their body weight. Furthermore, there was a reduction in the condition and quality of these females which influences the market value of the specimens.

We greatly reduced the possibility of biases associated with high mortality in winter and spawning in summer by rejecting the data from the last period of each experiment, after day 75. The very high mortality observed in our winter experiment after 17 April (day 75) was attributable to a decrease in salinity to below 29 psu, the approximate lower limit of the range of tolerance for *O. vulgaris* (Mangold, 1983). The high incidence of spawning and of mated females in the summer experiment was due to mating prior to the start of the experiment, since we kept the sexes separate. This is consistent with the known late-spring and summer peak spawning season in Galician waters (González *et al.,* 2005).

We recognize that there were also mortalities throughout the first 75 days of each experiment and that there was probably some spawning within the first 75 days. Both mortality and spawning were more prevalent in the summer than the winter experiment, especially in the second period (day 31-75). Therefore we consider our results from the first period (day 0-30) of both experiments to be the most reliable. This is reflected by the consistency of our results for the first period, since growth rates were higher for both sexes during this period in both experiments, and were higher in summer than winter for both sexes.

Mortality did not affect growth rate estimates, especially during the first period (day 0-30), when it was relatively low. Mortality introduces bias to growth rate estimates only if they are size-dependent (Ricker, 1975). Size-dependence was unlikely, especially during the first period because of the very limited variability in initial size of the animals selected for each experiment. While cannibalism would represent a possible source of size-dependent mortality, we observed little evidence of cannibalism. Furthermore, cannibalism is promoted, not only by large variations in size among animals, but also by limitations in alternative food sources (Boyle, 1980; Gonçalves, 1993, Hanlon and Messenger, 1996), neither of which was the case in our experiments. Segregation of sexes and an excess of dens also probably contributed to low cannibalism.

The relatively high mortality experienced during our summer experiment was associated with the presence of ulcers in the mantle, which affected epithelial, sub-epithelial and even muscular layers. The shape and location of these ulcers coincided with those described by Gonçalves (1993) and Sendao-Silva (1997), for this species, and by Hanlon *et. al*. (1984), for *Octopus joubini* and *Octopus briareus*. The macroscopic characteristics of these ulcers and their location in the posterior-dorsal region of the mantle suggest that they were caused by pathogenic agents which colonized the mantle through small wounds in the skin. These wounds were predominately caused by contact with the walls of the cages, as noted by Gonçalves (1993) and Sendao-Silva (1997), for *O. vulgaris*, as well as by Hanlon *et al*. (1984) and Hanlon and Forsythe (1990) for other octopodids. This source of mortality was independent of size.

It is highly unlikely that our summer growth rate estimate for females was biased by including spent specimens in our samples taken on days 30 and 75. We would have recognized spent females, as they have a poor physical condition. However, our sampling method, which selected only from those animals swimming freely in the bottom of the cages, would introduce a bias because it would have excluded spawning females that would have remained in dens guarding their egg masses. Thus, we do recognize that the high energetic cost of maturing ova, relative to that of somatic growth was probably responsible for the considerable decrease in G that was observed in females between the first and second period of the summer experiment (2.27 and 0.93 respectively).

On the whole, it could be suggested that the great variability observed in the growth rates of several experiments could be due to at least several factors: salinity, feeding composition, feeding ratio, size of the animals at the start of the trial, number and type of dens, initial density of animals, etc.

Our study illustrates the considerable potential for maintaining *O. vulgaris* at relatively high densities, especially during summer, to increase both the yield and market value of small specimens. Our experiments suggest that culture may represent a viable alternative to commercial *O. vulgaris* fishery. The high mortality we observed due to heavy rainfall and decreased salinity is avoidable by situating platforms in areas of the Rias that are not strongly influenced by river runoff. The negative effects of the spawning events during summer could be minimized by removing females once the first signs of spawning are detected. Commercial viability is enhanced by using readily-available mussel-culture rafts as platforms from which to suspend cages. The development of a common octopus ongrowing industry in Galicia would increase the total income from fishing by enhancing the market value of the small specimens that currently prevail in the commercial catch. However, sourcing animals for culture from small-scale fishery would represent an undesirable increase in fishing pressure on the resource. One possible solution to this problem, currently being intensively studied, is rearing paralarvae. This involves improving experimental rearing systems as well as making studies that combine exploratory experiments with field sampling (Villanueva, 1995). Thus, innovative studies have been conducted lately to shed light on the rearing of paralarvae in an attempt to succeed in culturing the early stages of this commercially important cephalopod species, using both natural and artificial diets and increasing the survival rates of hatchlings (Carrasco *et al.,* 2003; Villanueva *et al.,* 2004; Iglesias *et al.,* 2004).

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