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Growth, fatness and gross biochemical composition of the japanese oyster Crassostrea gigas in stanway cylinders in the bay of Arcachon, France

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ABSTRACT

The Stanway cylinder was tested in the bay of Arcachon from September 1989 to August 1991. Trials were mainly performed on the Japanese oyster *Crassostrea gigas* in a wind-exposed area. The seed, spat, 18 month old oysters development and fattening of 2 year old oysters were studied. Compared to plastic bags the Stanway cylinder has high positive effects on survival and growth of *Crassostrea gigas* seed. It also has positive effects on commercial sized *Crassostrea gigas* fattening. Nevertheless, the cylinder has negative effects on the growth of *Crassostrea gigas* spat and 18 month old oysters, except for width. However, oyster quality is greatly improve : higher condition index, higher carbohydrate contents and higher shell densities were recorded. Because Arcachon oyster industry is affected when selling generally poor meaty oysters with fragile and friable shells during the height of the season, November to January, the use of the cylinder for rearing 18 month old oysters is advantageous. To increase the efficiency of the system, the cylinder could be locked during the growing periods.

mots clés : *Crassostrea gigas*, croissance, technique d'élevage bassin d'Arcachon.

key words : *Crassostrea gigas*, growth, culture methods, bay of Arcachon.

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SUMMARY

GROWTH, FATNESS AND GROSS BIOCHEMICAL COMPOSITION OF THE JAPANESE OYSTER CRASSOSTREA GIGAS IN STANWAY CYLINDERS IN THE BAY OF ARCACHON, FRANCE.

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Introduction.

The Stanway cylinder was tested in the bay of Arcachon from September 1989 to August 1991. The first trials, concerning seed development only, were carried out during six months, from September 1989 to March 1990. Three shellfish species, *Ostrea edulis*, *Ruditapes philippinarum* and *Crassostrea gigas*, were tested during the nursery stage, using two different methods: the Stanway cylinder and the traditional plastic oyster bag. For the first two species, growth rates and mortalities were similar for both techniques, and so further research was unnecessary. However, the cylinder seemed to be advantageous for the Japanese oyster *Crassostrea gigas* but the results were insufficient to show clearly the advantages of this new technique. The use of uncalibrated *Crassostrea gigas* seed and the poor growth recorded during the experimental period (autumn and winter), may explain this. Consequently, new trials were carried out on this last species. The results concerning the experimental period, September 1989 - March 1990, have been reported elsewhere (Robert and Maurer, 1991) and will not be detailed here.

Materials and methods.

All the trials were performed in a wind-exposed area "La Humeyre" on intertidal ground (Fig. 1). As previously described, cares were taken to reinforce the structures (metallic tables and rods) and to respect oyster immersion time (cylinders and bags at similar bathymetric levels at low tide).

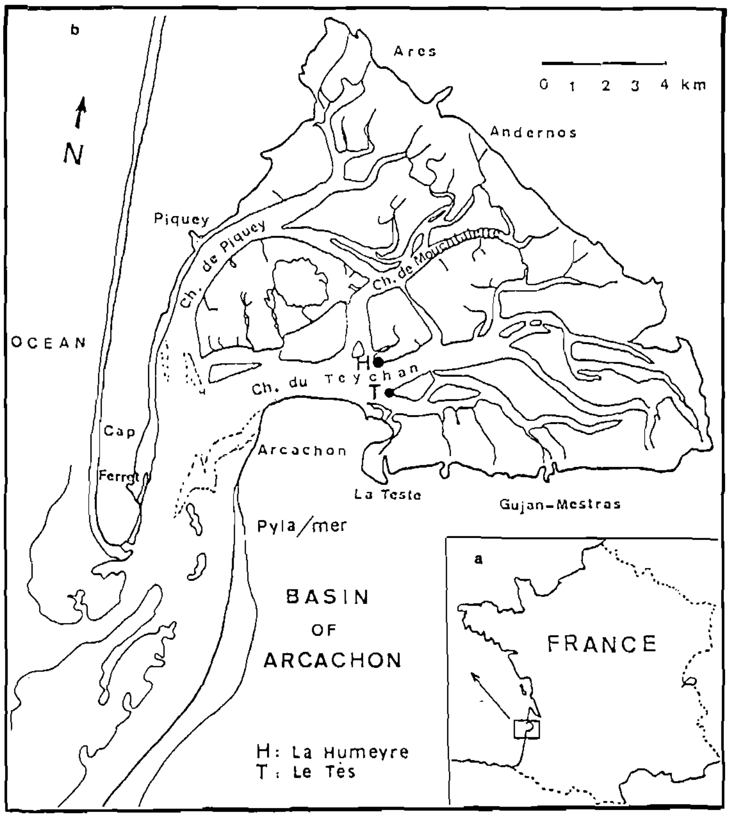

Fig. 1. (a) Map of France, showing location of study area; (b) experimental station used for monitoring *Crassostrea gigas* cultures in the present study.

To try to determine the long-term influence of the cylinder on the growth and quality of the Japanese oyster, trials were performed from March 1990 to August 1991. On the one hand, calibrated *Crassostrea gigas* spat were homogenized and placed in three cylinders and three bags (4 mm mesh-size) at a density of 500 individuals per cylinder or bag. The spat were initially 6 to 8 months old (settlement in the bay in summer 1989) with a mean height of 20 mm and mean weight of 3 g.

On the other hand, 18 month old oysters were placed in three cylinders and three bags (9 mm mesh-size) at a density of 250 individuals per cylinder or bag. The young oysters were 60 mm high and weighed 20 g, initially.

In each experimental unit (cylinder or bag) and for each grade, a sample of 20 individuals was randomly taken each second month from March 1990 to April 1991. After collection, spat and oysters were rapidly transported to the laboratory and weight, height, length and width were measured according to Galstoff (1964) (Fig. 2).

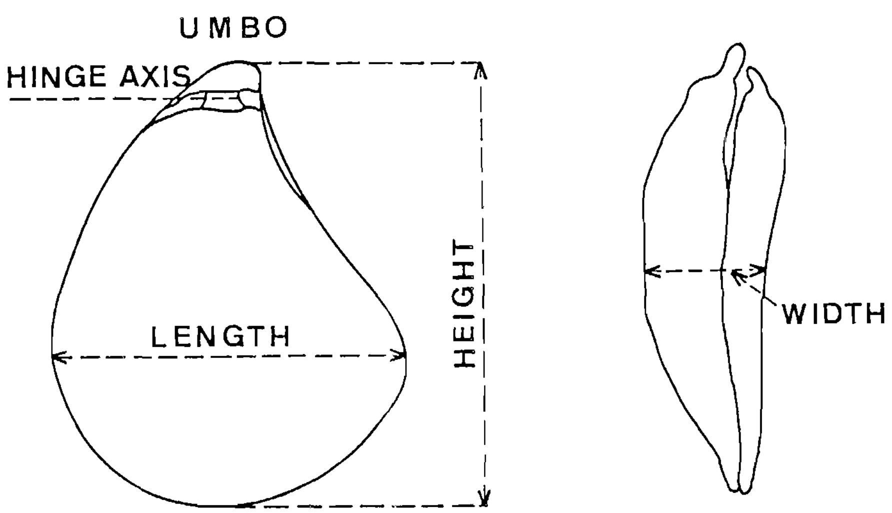

Fig. 2. Diagram showing the biometric measurements used in the present study.

Mollusc fatness was estimated by changes in dry meat weight (after 48 h lyophilization) and pooled condition index (defined as 1000 * dry meat weight / internal volume: Medcoff and Needler 1941). Individual condition index were performed at the end of the survey in April 1991. Biochemical composition was also recorded using vacuum-dried pooled tissue (10 to 20 individuals) as recommended by Giese (1966). For each component 3 to 5 g of homogenized tissue was used and all measurements performed in duplicate. The methods of Dubois *et al.* (1956), Bligh and Dyer (1959), Marsh and Weinstein (1966) and Lowry *et al.* (1951) were used to determine the carbohydrate, lipid and protein levels, respectively. The biochemical results were expressed in percentage of ash-free dry weight. The ash proportion was estimated after incinerating tissue homogenate in a muffle furnace at 500° C during 24 h. Some observations on gametogenic development were also realized by means of microscopic observations after piercing the gonad and 4 arbitrary stages according to Marteil (1960) were used to describe the reproductive cycle. Shell quality was estimated by changes in dry shell weight, pooled density, chambering and *Polydora* sp. infestation rates. In the figures the mean data correspond to triplicate values recorded in cylinders or bags. Differences in height, weight, meat dry weight, condition index and shell density, between treatments (bags or cylinders) were assessed using one way analysis of variance (ANOVA) on data recorded in April 1991.

Also, uncalibrated *Crassostrea gigas* seed, 3 to 4 months old, purchased from tile scraping (1990 summer reproduction), were homogenized and placed in November 1990, in one bag and one cylinder (4 mm mesh-size), at a density of 1500 ml per experimental unit (≈700 individuals). Weight and height were initially recorded on a sample of 30 individuals per experimental unit. Weight, height, length, width and condition index were recorded, in August 1991, on a sample of 100 individuals per experimental unit. The mortality rate, total volume and total weight were recorded on whole populations. Differences between treatments were assessed using t tests.

To try to determine the short-term influence of the cylinder on meat and shell qualities of adult oysters, 2 year old *Crassostrea gigas*, at a commercial size (85 mm height - 65 g weight) were placed in three cylinders and three bags from September 1990 to December 1990. This period was chosen because during this last month the French market's demand of oysters is high. Three densities were tested in cylinders, 250, 200 and 150 individuals. The oysters were placed in bags, at the density of 150, which is the density commonly used by oyster farmers for fattening. In each experimental unit, a sample of 30 individuals was randomly taken monthly and weight, dry meat weight, dry shell weight, shell density, condition index, carbohydrate and glycogen contents were measured. Differences between treatments were assessed using t tests in December 1990.

On the other hand, chlorophyll *a*, salinity and temperature were monitored weekly at Le Tès, a reference station localized near La Humeyre (Fig. 1). Temperature and salinity were measured with a portable T-S meter (YSI model

33). For chlorophyll determinations, 100 cc of seawater was filtered on GF/C membranes. Filters were kept in an ice box for fluoremeter analysis (Turner model 112), according to Lorenzen (1967).

Results.

Seed development.

Results are shown in Table 1. Better survival and significantly better growth rates were recorded in the cylinder. Similar results were achieved previously but differences were not statistically significant, except weight (Table 2).

Spat development.

Mortality was low, less than 10% in bag or cylinder.

Compared to spat from bags, growth in height was lower in cylinders (Fig. 3 a) and in April 1991, a significant difference of 25 mm in average size was noted (Table 3). From February to October 1990, an increase in growth rates was noticed to be higher in the bags. Spat displayed poor growth in autumn and winter. Growth in length followed similar patterns (Fig. 3 b) and the spat from the bags were 10 mm higher in April 1991. There was an obvious slowing down in size, which was noted to be higher in bags, during winter, which may be associated to storms. Little differences in width were observed between batches (bags or cylinders). From

Variable n° 1 HEIGHT

SOURCE OF VARIATION	Spat				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	14 229.20	17.99	***	99
RESIDUAL (error)	114	18 032.20			
TOTAL	119	32 261.20			

Variable n° 2 WEIGHT

SOURCE OF VARIATION	Spat				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	2 007.58	1.87	NS	71
RESIDUAL (error)	114	24 476.35			
TOTAL	119	26 483.93			

Variable n° 3 MEAT DRY WEIGHT

SOURCE OF VARIATION	Spat				
	DF	SUMM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	2.04	2.61	***	82
RESIDUAL (error)	114	17.81			
TOTAL	119	19.85			

Variable n° 4 CONDITION INDEX

SOURCE OF VARIATION	Spat				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	77 505.77	39.78	***	99
RESIDUAL (error)	114	44 422.93			
TOTAL	119	121 928.70			

Variable N° 5 SHELL DENSITY

SOURCE OF VARIATION	Spat				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	2.42	9.42	***	99
RESIDUAL (error)	114	5.86			
TOTAL	119	8.28			

Table 3 : Effects of technique (bag or cylinder) on height, weight, meat dry weight, condition index and shell density of Crassostrea gigas spat. One way analysis of variance were made at the end of the survey, in April 1991.
1 - β : power of the test ; *** : significant at p = 0.001 ;
NS : not significant.

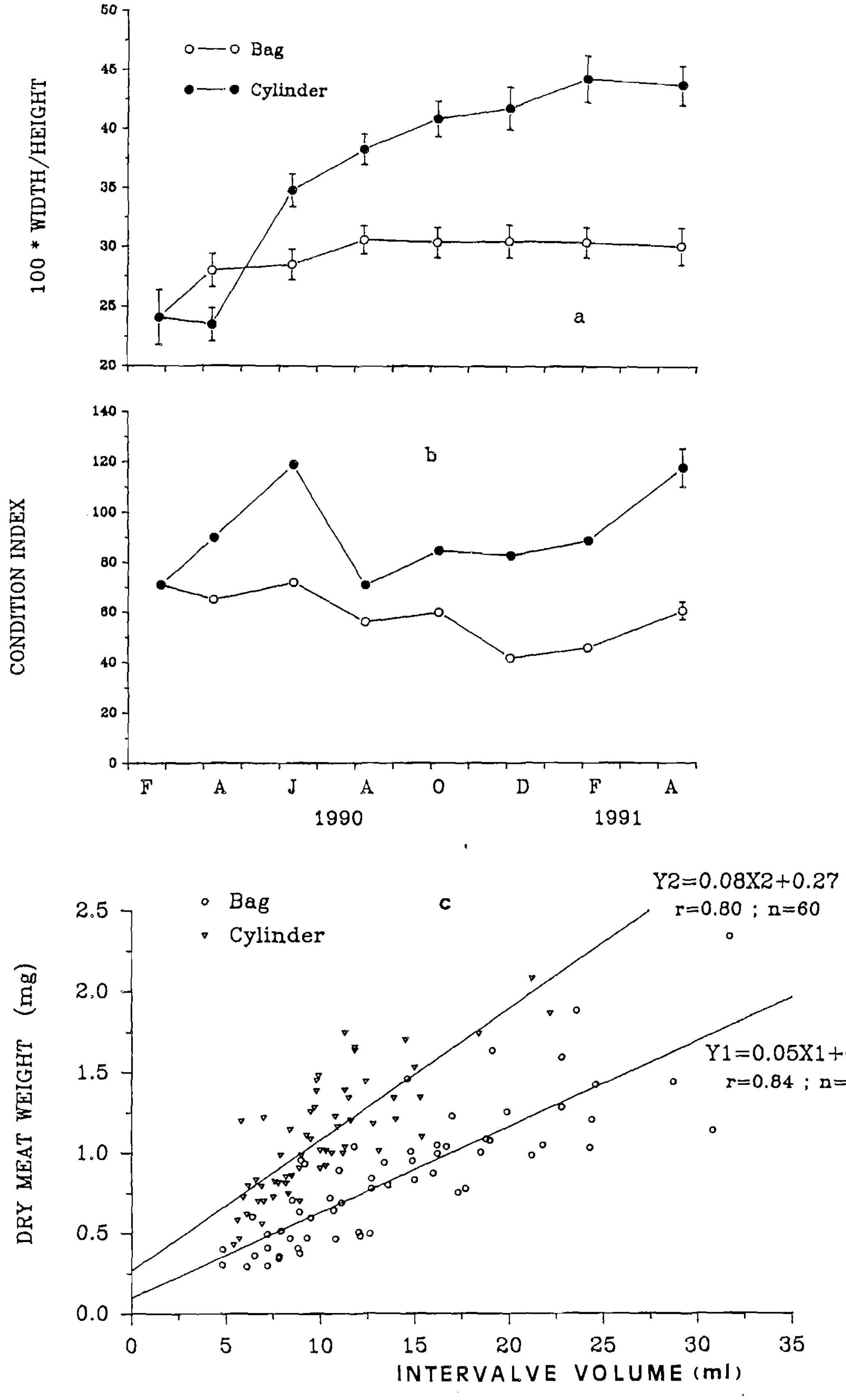

Fig. 5. Seasonal variations of the ratio width/height (a) and condition index (b) of *Crassostrea gigas* spat, reared in oyster bags or Stanway cylinders, in the bay of Arcachon, from February 1990 to April 1991. Data are means ± 95% confidence intervals. Regression lines of the intervalve volume on the dry meat weight on data achieved in April 1991 (c).

February to August 1990, the spat from the bags were thicker, followed by an opposite trend (Fig. 3 c).

Growth in weight was higher in bags during the first year, but the difference recorded in April 1991 was not significant (Fig. 4 a; Table 3). From February to October 1990, weight sharply increased, followed by a slowing down during autumn and winter. Dry shell weight (Fig. 4 b) followed similar patterns but dry meat weight did not (Fig. 4 c). Indeed, from December 1990 to April 1991, spat from cylinders exhibited better growth rates in dry meat weight (Table 3).

Compared to bags, cylinders had negative effects on *Crassostrea gigas* spat growth, except for width. However the differences in width between spat from bags and spat from cylinders were minimized by the fact that width increased with length. The evolution of the ratio width/height was constant for spat from bags but increased for spat from cylinders (Fig. 5 a). For similar length, spat reared in cylinders were thicker.

Compared to bags, cylinders had positive effects on *Crassostrea gigas* spat quality as indicated by higher condition index for spat from cylinders (Fig. 5 b; Table 3). On data achieved in April 1991, the lines of the intervalve volume on the dry meat weight showed positive regressions (Fig. 5 c). For similar intervalve volume values, higher dry meat weight values were recorded in cylinders.

From February to August 1990, little or no differences in carbohydrate contents between batches were noted (Fig. 6 a). Spat from cylinders showed higher carbohydrate contents during autumn and winter. Lipid contents evolved in different

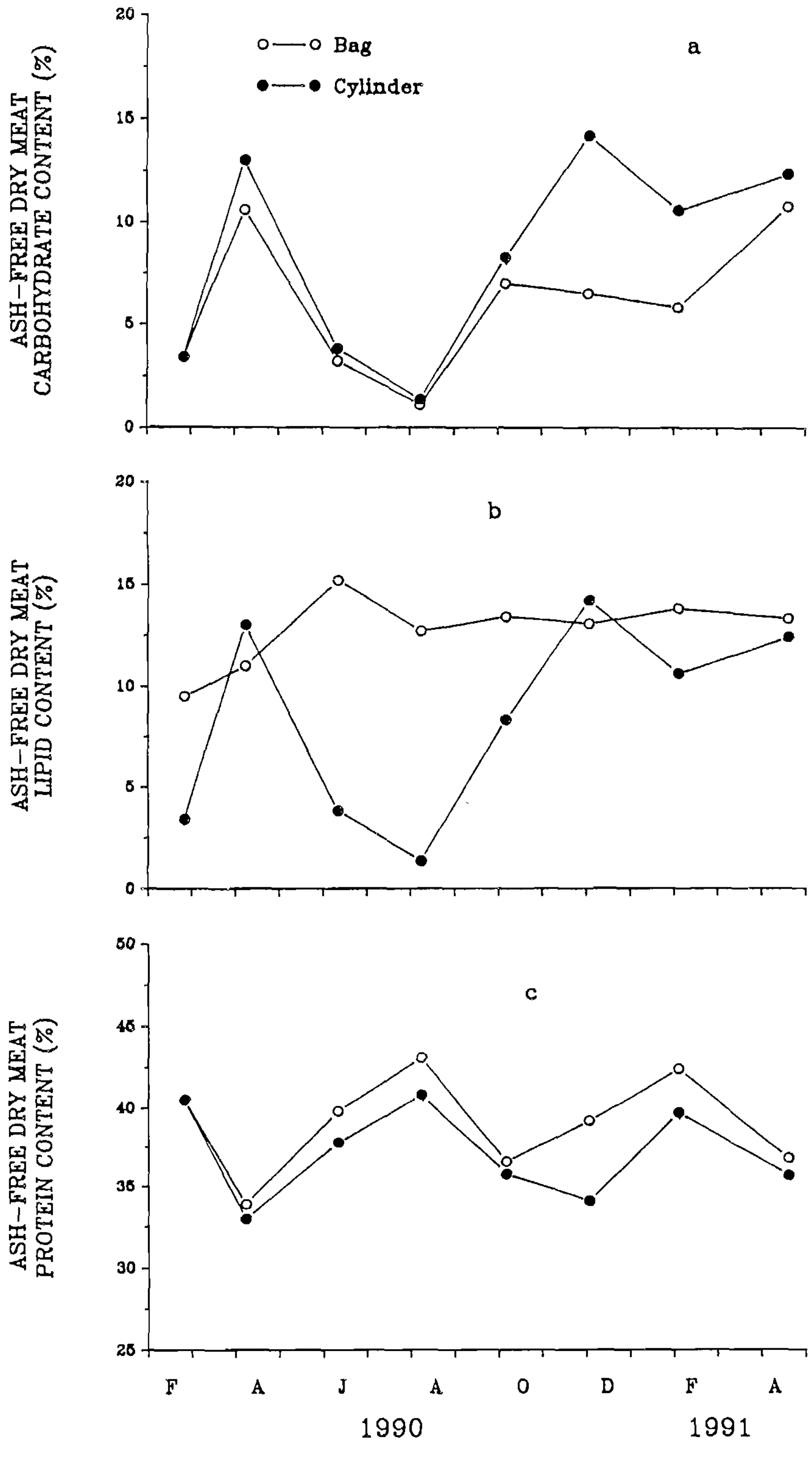

Fig. 6. Seasonal variations in total carbohydrate (a), lipid (b) and protein contents (c) of *Crassostrea gigas* spat, reared in oyster bags or Stanway cylinders, in the bay of Arcachon, from February 1990 to April 1991.

patterns (Fig. 6 b) which may result from earlier maturation and spawning for spat from cylinders. Indeed, in June 1990 the whole population was ripe while only 40 % of the spat from bags attained this stage. Little differences in protein contents between batches were noted (Fig. 6 c)

Spat from cylinders exhibited better shell quality with significant higher shell densities (Fig. 7 a; Table 3). Differences in shell density may be partially explained by differences in chambering and *Polydora* sp. infestation rates (Figs. 7 b, c).

18 month old oysters development.

Similar results were found with 18 month old *Crassostrea gigas* oysters. Mortality was low, less than 5% in bags or cylinders.

Lower growth rates in height, length and width were recorded on oysters from cylinders (Figs. 8 a, b, c) with differences between batches of 30 mm (highly significant: Table 4), 10 mm and 5 mm in April 1991, respectively. A higher dispersion of height values was recorded in April 1991 in bags, with a coefficient of variation of 28% (vs 19% in cylinders).

Oysters from cylinders exhibited lower growth rates in weight with a significant difference of 25 g between batches in April 1991 (Fig. 9 a; Table 4), also partially explained by differences in dry shell weight (Fig. 9 b) but not in dry meat weight (Fig. 9 c; Table 4). Dispersion in weight values were

Variable n° 1 HEIGHT

SOURCE OF VARIATION	18 month old oysters				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	17 531.07	32.83	***	99
RESIDUAL (error)	114	12 174.90			
TOTAL	119	29 705.97			

Variable n° 2 WEIGHT

SOURCE OF VARIATION	18 month old oysters				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	16 321.86	12.74	***	99
RESIDUAL (error)	114	29 218.80			
TOTAL	119	45 540.80			

Variable n° 3 MEAT DRY WEIGHT

SOURCE OF VARIATION	18 month old oysters				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	2.03	1.67	NS	66
RESIDUAL (error)	114	27.71			
TOTAL	119	29.74			

Variable n° 4 CONDITION INDEX

SOURCE OF VARIATION	18 month old oysters				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	60 262.25	31.16	***	99
RESIDUAL (error)	114	82 362.61			
TOTAL	119	142 624.86			

Variable n° 5 SHELL DENSITY

SOURCE OF VARIATION	18 month old oysters				
	DF	SUM OF SQUARES	F (ratio)	P	1 - β %
FACTOR (Technique)	5	1.19	4.19	***	95
RESIDUAL (error)	114	6.45			
TOTAL	119	7.64			

Table 4 : Effects of technique (bag or cylinder) on height, weight, meat dry weight condition index and shell density of Crassostrea gigas 18 month old oysters. One way analysis of variance were made at the end of the survey, in April 1991.
1 - β : power of the test ; *** : significant at p = 0.001 ;
NS : not significant.

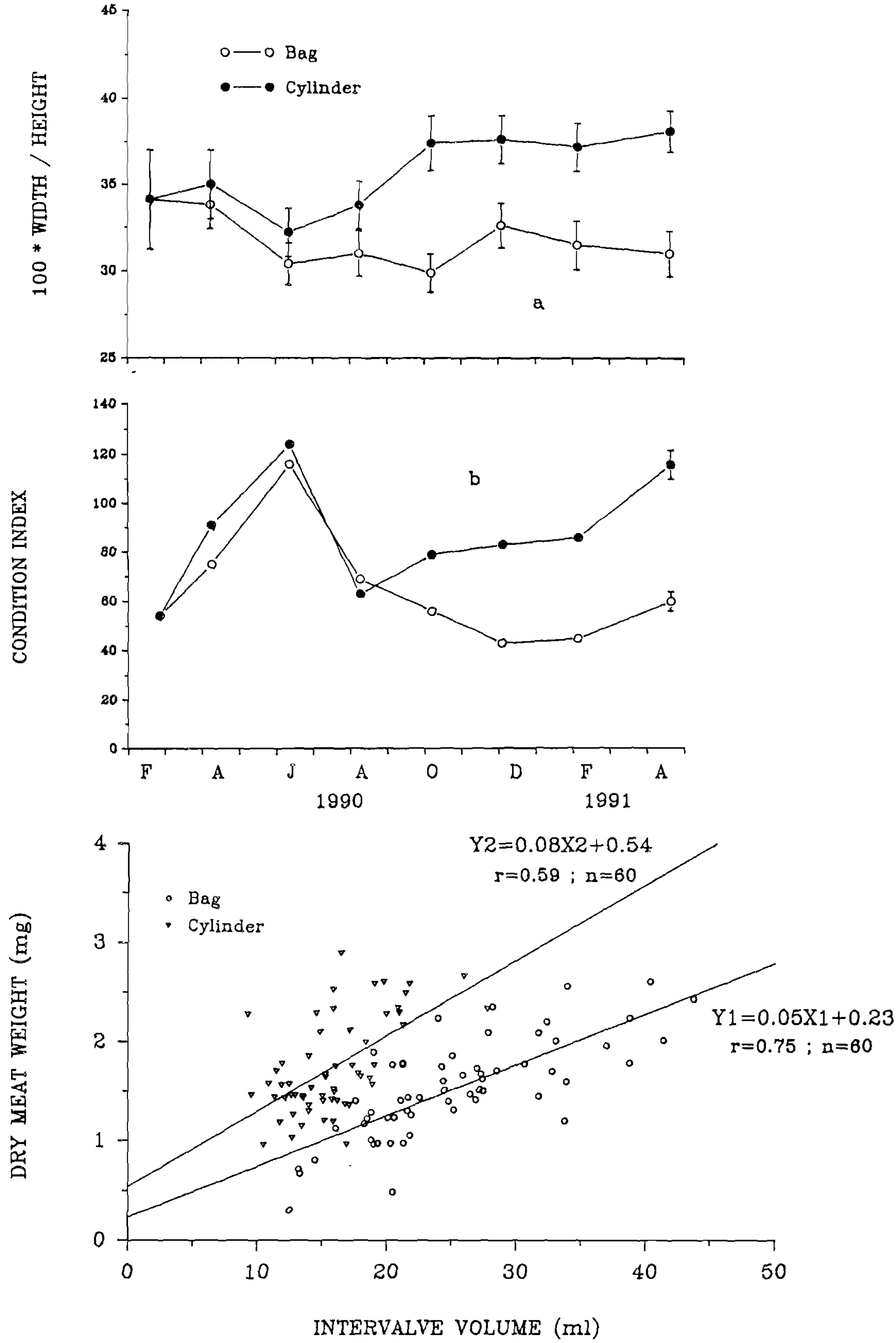

Fig. 10. Seasonal variations of the ratio width/height (a) and condition index (b) of 18 month old *Crassostrea gigas* oysters, reared in oyster bags or Stanway cylinders, in the bay of Arcachon, from February 1990 to April 1991. Data are means ± 95% confidence intervals. Regression lines of the intervalve volume on the dry meat weight on data achieved in April 1991 (c).

also higher in bags with a coefficient of variation of 14% (vs 7% in cylinders).

Compared to bags, cylinders had negative effects on 18 month old *Crassostrea gigas* growth, except for width. Indeed, the evolution of the ratio width/height increased for oysters from cylinders (Fig. 10 a) and for individuals of similar length, oysters reared in cylinders were thicker.

Compared to bags, cylinders had positive effects on *Crassostrea gigas* oyster quality, as indicated by generally higher condition index for oysters from cylinders (Fig. 10 b; Table 4). In December 1990, the index values were very different: 43 in bags and 83 in cylinders. On data achieved in April 1991, the lines of the intervalve volume on the dry meat weight showed positive regressions (Fig. 10 c). For similar intervalve volume values, higher dry meat weight values were recorded in cylinders.

Higher carbohydrate contents were found in oysters from cylinders (Fig. 11 a), while little differences were noted between batches in lipid and protein contents (Fig. 11 b, c)

Oysters from cylinders exhibited better shell quality as indicated by significantly higher shell densities (Fig. 12 a; Table 4) which may be associated to lower shell chambering rate (Fig. 12 b), but not to lower *Polydora* sp. infestation (Fig. 12 c).

Fattening.

The cylinder 250 did not rotate normally because of high initial oyster weight (16 kg). The results will only

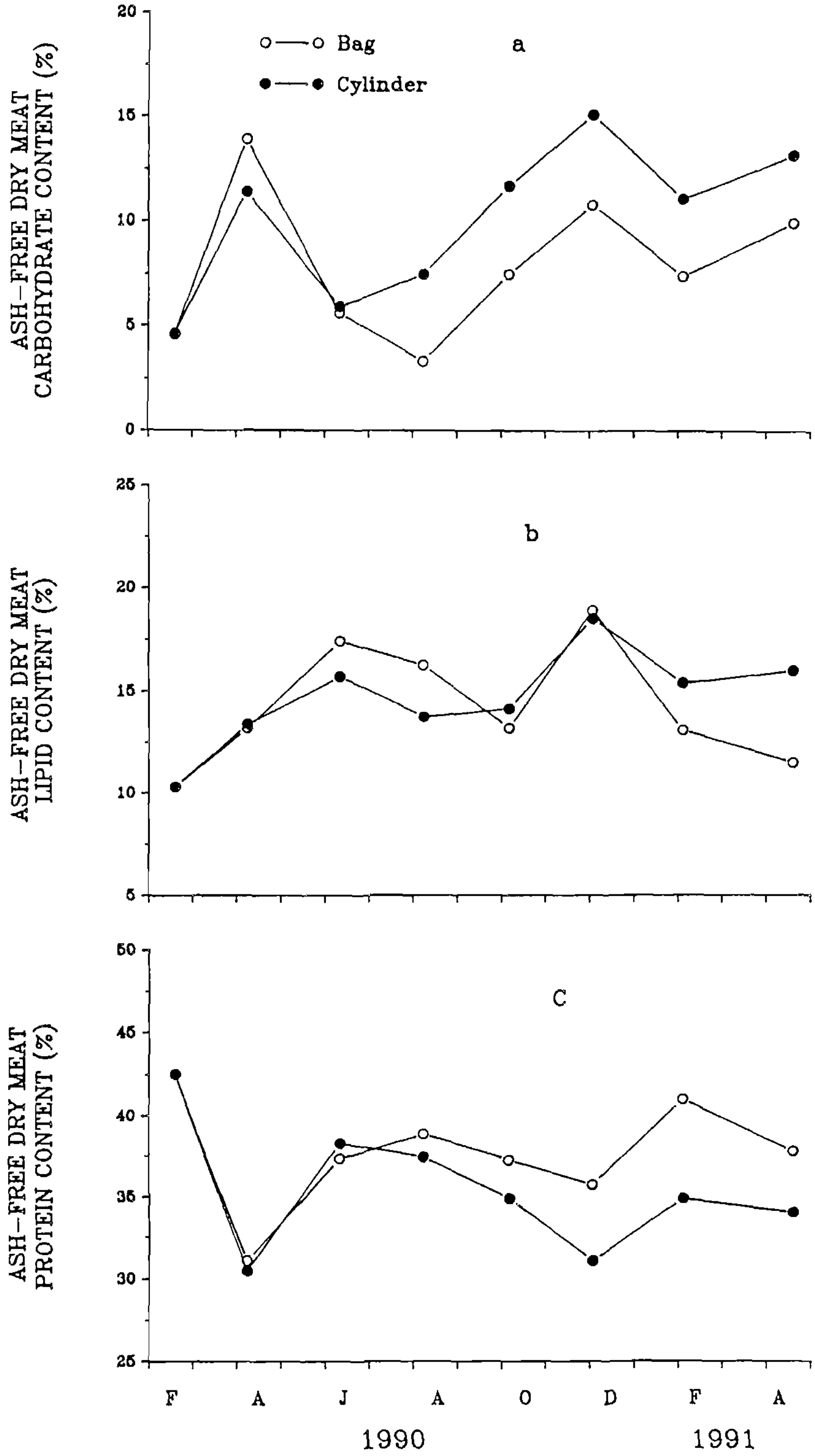

Fig. 11. Seasonal variations in total carbohydrate (a), lipid (b) and protein contents (c) of 18 month old *Crassostrea gigas* oysters, reared in oyster bags or Stanway cylinders, in the bay of Arcachon, from February 1990 to April 1991.

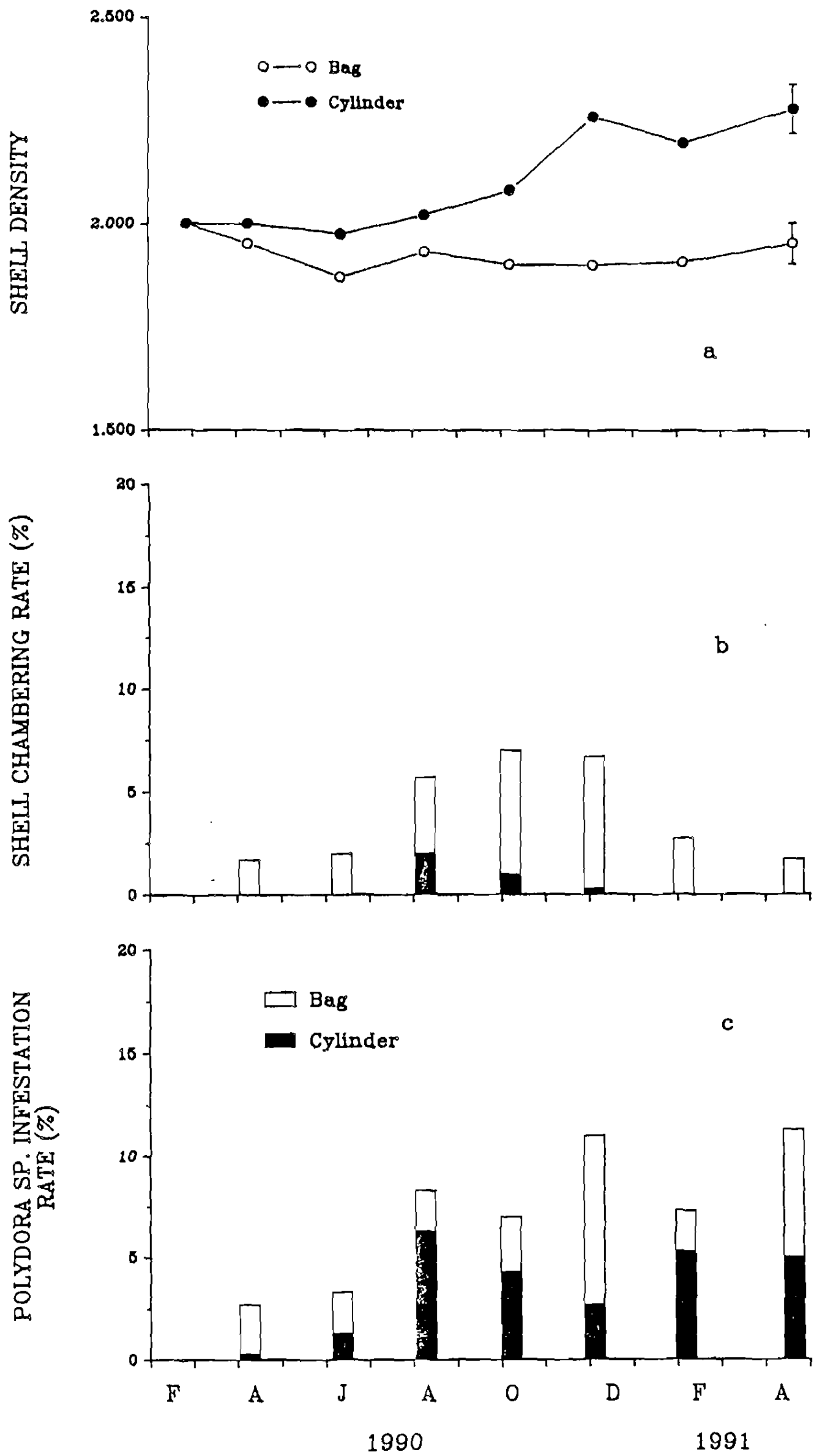

Fig. 12. Seasonal variations in shell density, shell chambering and *Polydora* sp. infestation rates of 18 month old *Crassostrea gigas* oysters, reared in oyster bags or Stanway cylinders, in the bay of Arcachon, from February 1990 to April 1991.

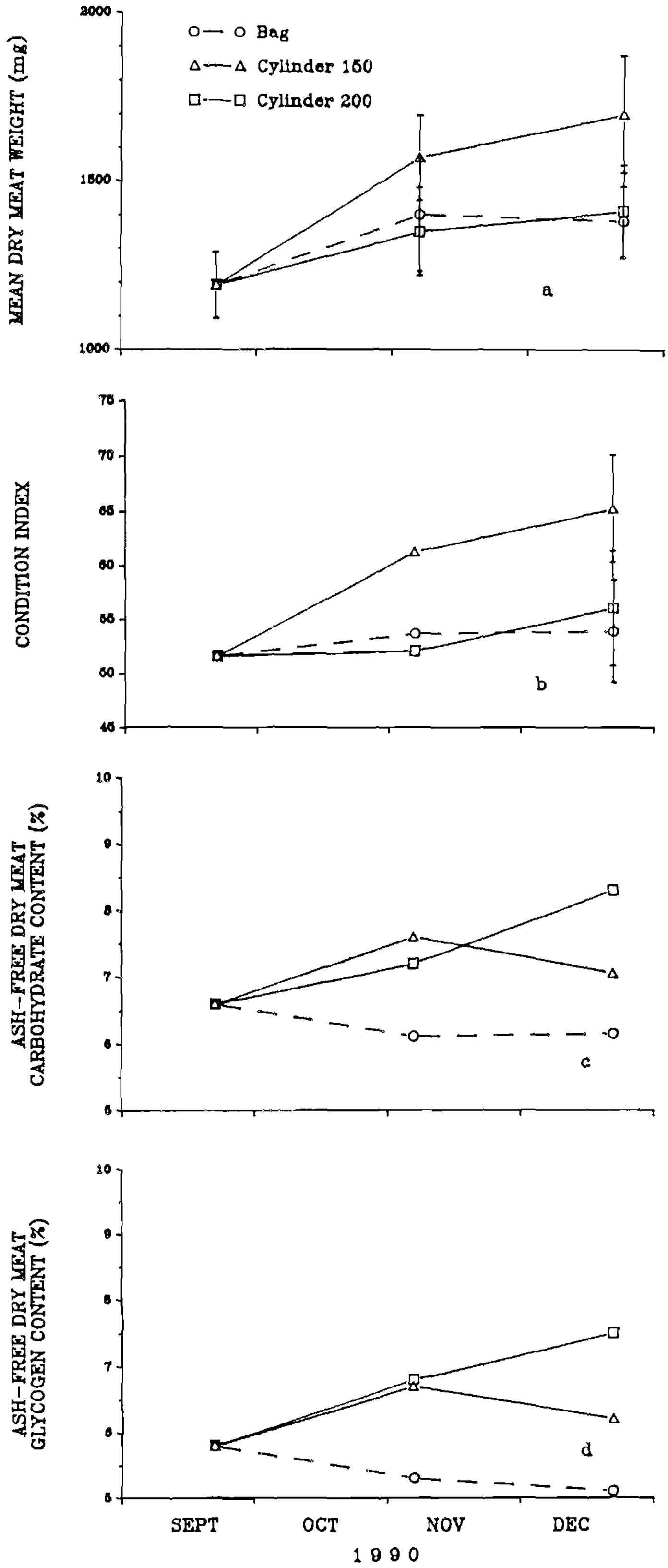

Fig. 14. Dry meat weight (a), condition index (b), total carbohydrate (c) and glycogen contents (d) of 2 year old *Crassostrea gigas* oysters, fattened in oyster bags or Stanway cylinders, in the bay of Arcachon, from September to December 1990. Data are means ± 95% confidence intervals.

concern densities of 100 and 150. After three months there were little or no differences between batches in weight and shell density (Fig. 13 a, b). In contrast, oysters from cylinders 150 exhibited higher dry shell weight at $p = 0.05$ (Fig. 13 c), higher dry meat weight at $p= 0.01$ (Fig. 14 a), and better condition index at $p= 0.01$ (Fig. 14 b). Moreover, higher carbohydrate contents were observed in cylinders at both densities (Fig. 14 c). The glycogen contents followed similar patterns and represented 85 to 90 % of total carbohydrates (Fig. 14 d).

Hydrobiological survey.

From February 1990 to April 1991, four phytoplankton blooms were recorded at Le Tès with values exceeding 5 mg m^{-3}; the first occurred in winter 1990, the second in spring, the third in summer and the last in autumn 1990 (Fig. 15 a). The salinity fluctuated from 34 ‰ in summer 1990 to 22 ‰ in winter 1991 (Fig. 15 b), while the temperature decreased from 25° C in July 1990 to 3° C in February 1991 (Fig. 15 c).

Discussion and conclusions.

The Stanway cylinder has high positive effects on survival and growth of *Crassostrea gigas* seed (tile scraping). On the one hand, the revolving action helps remove silts and algae from around seed and on the other hand, enables the whole population to feed better by preventing choking. For nursing *Crassostrea gigas*, the seed has to be scraped off from tiles in September-October and placed in cylinders for 4 to 6 months. In the present work no data has been achieved on the effects of stocking density in cylinders. Nevertheless, such results have been reported on Sydney rock oyster, *Saccostrea commercialis* by Holliday *et al.* (pers. com.). These authors showed that for maximum growth, seed oysters should be stocked at low densities of 0.5 to 1.0 l/cylinder for 0.2 and 0.4g/spat, respectively. However, to maximise biomass gain, higher densities of 2 to 3 l of oysters per cylinder should be used. These densities could be successfully used by oyster farmers for nursing *Crassostrea gigas*. Furthermore, the cylinder has positive effects on commercial sized *Crassostrea gigas* fattening. At the density of 150 which is commonly used by oyster farmers, a better growth meat, a higher condition index and higher carbohydrate contents are recorded in cylinders. On the other hand, the appearance and texture of the shells are improved: shells are cleaner and smoother. But, for the single operation of fattening, the cylinder seems to be ineffective because of capital and operating costs. This operation needs to be integrated in a complete cylinder oyster growing method, detailed below.

In contrast, the cylinder has negative effects on growth of *Crassostrea gigas* spat and 18 month old oysters, except for width. After a culture for one year, the heights of spat and 18 month old oysters, reared in cylinders, are 25 to 30 mm less than in bags. Lower growth rates in weight are also recorded with 18 month old oysters which may result from hydrological conditions of the bay. Although the bay of Arcachon is a well-sheltered oyster area, tidal currents are rather strong reaching 2 m/s. Moreover, the experimental station was exposed to a North-Westerly wind and was poorly protected from wave action. Spat and oysters were probably vigourously tumbled in cylinders resulting in severe shoot breakage.

Because of excellent environmental conditions, the bay of Arcachon is the best *Crassostrea gigas* spating area in the whole of France. Spatfall is very high and may reach 10^{10} in the whole of the bay (Maurer and Borel, 1990) and spat growth is excellent. Consequently, there is a great demand in Arcachon for *Crassostrea gigas* spat with 35 to 55% of spat sale to other regions. Because of lower size growth induced, the cylinder seems to be disadvantageous for rearing spat.

In contrast, size reduction of 18 month old oysters seems not to be a real problem because of oyster quality improvement. On the one hand, higher condition index and higher carbohydrate contents were generally found, especially in autumn and winter. That means that after spawning, the cylinder revolving action promotes recovery. This fact is very important for Arcachon oyster industry which is affected when selling generally poor meaty oysters during the height of the season, from November to January. On the other hand, the cylinder induces higher shell density and improves the appearance and texture of oyster shells. Because of high height growth, Arcachon oyster shells are generally fragile and friable which also restrains Arcachon oysters from commercialization. Because of the improvement of oyster quality, the use of the cylinder for rearing 18 month old oysters is advantageous. Nevertheless, reduction in size may be negatively considered by oyster farmers. In the bay of Arcachon *Crassostrea gigas* growth occurred during spring and summer (Maurer, 1989). To increase the efficiency of the system, the cylinder could be locked during these growing periods and unlocked during autumn and winter, during which no or little growth occurred in the bay.

Acknowledgements.

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POST SCRIT

(by Stanway)

Our experience with the cylinder in three years of practical growing of oysters for sale confirms that damaging the growing edge or shoot will retard growth. This would have accounted for the slower growth (particularly of height) mentioned in this report.

Also the very low numbers of oysters in each cylinder used in the experiments would increase the agitation of both the cylinder and the enclosed oysters in violent weather ; in practice up to ten times the numbers mentioned in the report would be put in a cylinder.

The last paragraph on page 18 on this report states that cylinders have high positive effects on survival and growth of gigas seed. This is due to the revolving action removing silts and algae and also dispersing the oysters to enable better feeding by preventing choking.

Our experience has been that these advantages apply to all ages of oysters.

We have also found that the tumbling of larger oysters (at least half-grown but depending on the species) may damage the shoot and retard growth. This is overcome by stopping the rotation of the cylinder, or by transferring to trays or bags. The oysters are then tumbled in the cylinders for the last 3–6 months before harvest to harden the shell and improve the meat and also to prepare the oyster for the shock of transport.

Depending on water clarity and marine growth bags need attention about every 2–4 weeks while cylinders are unattended for 3–5 months.

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