Aquaculture Research, 1997, **28**, 611–619

Culture of the American oyster, *Crassostrea virginica* (Gmelin 1971) in Rio Lagartos, Yucatán, México

P Cabrera Rodríguez*, D Aldana Aranda & T Brulé
Laboratorio de Biología Marina, CINVESTAV-IPN, Unidad Mérida, A.P. 73 Cordemex, 97310 Mérida, Yucatán, México

E Amador del Angel
Facultad de Ciencias Pesqueras, Universidad Autónoma del Carmen, A.P. 28, Ciudad del Carmen, Campeche, México

*CRIP del Carmen, Av. Héroes del 21 de Abril s/n, Prolongación Playa Norte, Cd. del Carmen, Campeche, México

Correspondence: Dalila Aldana Aranda, Laboratorio de Biología Marina, CINVESTAV-IPN, Unidad Mérida, A.P. 73 Cordemex, 97310 Mérida, Yucatán, México

Abstract

This research was done with the purpose to ascertain the biological feasibility of the culture of *Crassostrea virginica* (Gmelin 1971) at Rio Lagartos lagoon in Yucatán, México. Spat from two localities of the Golfo de México were grown in Nestier boxes: spat from Tamiahua, Veracruz, which had an initial average height of 22.50 ± 5.10 (SD) mm and initial total wet weight of 2.90 ± 1.64 g and spat from Mecoacán, Tabasco, that were 32.05 ± 4.50 mm and 5.53 ± 0.03 g, respectively. Both groups of oysters reached commercial size after 10 months of culture. Veracruz spat reached 65.00 ± 6.80 mm in height and 33.26 ± 7.02 g in total wet weight. Those from Tabasco reached 62.90 ± 6.70 mm in height and 33.97 ± 9.95 g in total wet weight. The mean physiological condition index for oysters from Tabasco was 5.96% and from Veracruz was 4.52%. Total survival rate was 63% for spat from Veracruz and 55% from Tabasco. Environmental conditions in the culture area proved to be favourable for the rearing of *C. virginica*.

Introduction

The oyster *Crassostrea virginica* (Gmelin 1971) is a major fishery from the Mexican coast along the Golfo de México. The exploitation of natural beds constitutes 90% of the national oyster production. México ranks fifth in world production since 1974, and is the major oyster producer in the Caribbean. World oyster production reached 900 000 tons in 1990 (FAO 1992) with 345 000 of *C. virginica* from the Atlantic coast of the USA and the Golfo de México. Oyster exploitation is mainly from Veracruz and Tabasco, followed by Tamaulipas and Campeche (Palacios Fest & García 1987). There are no natural oyster beds in the coastal lagoons of Yucatán, in spite of Abbott's (1974) report of the presence of *C. virginica* on its coasts.

Interest in oyster culture in tropical zones is important as a renewable resource to produce proteins and provide an alternative source of employment. Attention has been focused on the development of suspension culture techniques, which have increased production.

In this study, the tray culture of *C. virginica* transplanted from Mecoacán, Tabasco and Tamiahua, Veracruz coastal lagoons to Rio Lagartos, Yucatán has been assessed. Growth, survival, and condition index of oysters were evaluated.

Materials and methods

Study area

Experimental site

The coastal lagoon of Rio Lagartos, Yucatán is located between 21°26′ and 22°38′N and 87°30′ and 88°15′W. It is 80 km in length and 4 km in width, with a depth that varies from 1–3 m (Fig. 1).

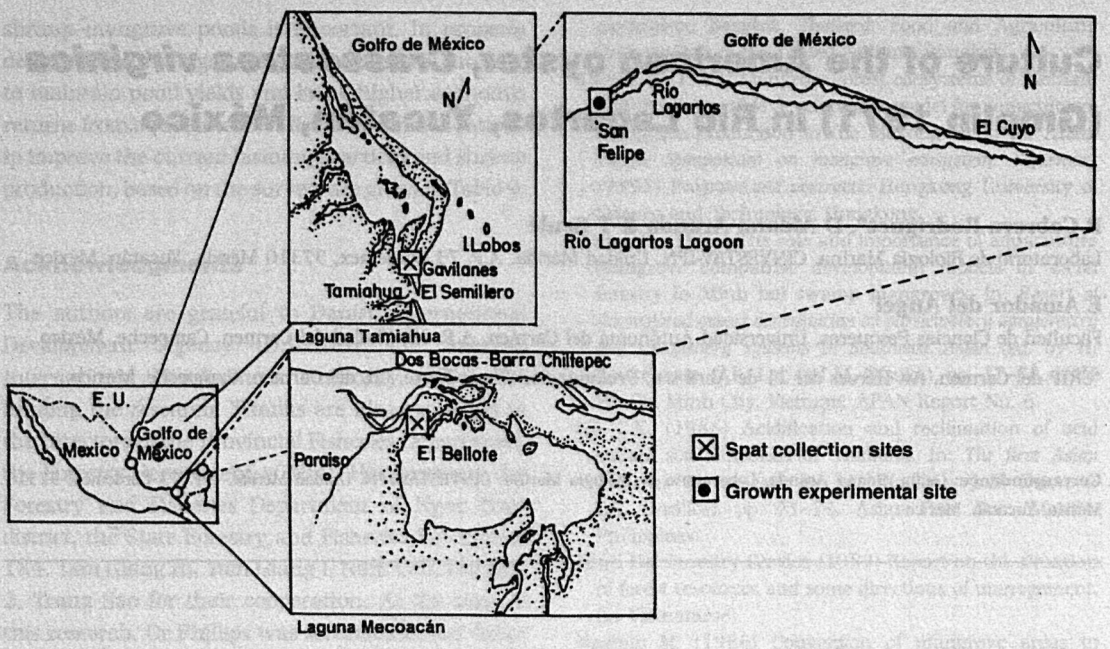

Figure 1 Spat collection sites (Laguna Mecoacán, Tabasco and Laguna Tamiahua, Veracruz) and growth experimental site in the Golfo de México.

The rainy season extends from July to November and there is a dry period from December to May. Mean water temperature is 29.9°C and salinity is 35.7 p.p.t. (Table 1).

Spat collection sites

Four hundred and fifty oysters of *C. virginica* were collected from each lagoon of the Golfo de México: Tamiahua, Veracruz and Mecoacán, Tabasco (Fig. 1). The spat were obtained from natural beds. They were separated with a knife and broken oysters were discarded. The oysters were transportated in isothermic containers at 16 ± 2°C. Before starting the experiment the oysters were observed for five days in the laboratory. They were counted, measured, and the total wet weight was recorded.

Laguna Tamiahua is located at Veracruz, between 21°06′ and 22°05′N and 97°22′ and 97°46′W. Mean annual water temperature is 27.5°C and salinity 21 p.p.t. (Cordero 1988). It is the second largest coastal lagoon of México: 115 km in length and 25 km in width, and the first in oyster production, accounting for 80% of national production.

Laguna Mecoacán is located at Tabasco between 18°28′N and 93°10′W. Mean water temperature and salinity are 26°C and 20 p.p.t., respectively (Cordero 1988). It is 11.5 km in length and 7 km in width, of which 3% is occupied by oyster beds.

Environmental factors

Water temperature was measured monthly with a mercury thermometer and salinity with a light refractometer. Chlorophyll 'a', particulate inorganic matter in suspension (PIMS) and particulate organic matter in suspension (POMS) were determined monthly by Boyd's (1981) methods. Dissolved Oxygen (DO) was measured by Winkler's titration (Strickland & Parson 1972).

Growth and physiological condition index

Growth was evaluated monthly according to Galtsoff (1964). Length, height, width and total wet weight were measured on 50 oysters selected randomly from each batch, for a 10-month period. The physiological condition index (PCI) was evaluated monthly on 10 oysters from each stock as the dry flesh weight : dry shell weight ratio (Lucas & Beninger 1985).

Table 1 Environmental factors values taken once monthly at Rio Lagartos, Yucatán

Months	Temperature C°	Dissolved Oxygen mg l^{-1}	Salinity p.p.t.	Chlorophyll 'a' mg l^{-3}	POMS mg l^{-1}	PIMS mg l^{-1}
March	28	5.5	34	2.4	0.0044	0.0250
April	33	4.2	30	3.7	0.0022	0.0240
May	28	6.2	32	2.2	0.0023	0.0200
June	30	9.1	35	2.3	0.0064	0.0110
July	31	7.8	34	1.1	0.0031	0.0150
August	33	7.7	40	5.3	0.0008	0.0130
October	28	7.2	40	2.1	0.0054	0.0110
December	30	8.3	38	2.3	0.0001	0.0200
February	28	7.0	38	1.8	0.0059	0.0120
Mean ± SD	29.9 ± 1.9	7 ± 1.42	35.7 ± 3.3	2.6 ± 1.19	0.0034 ± 0.0021	0.0168 ± 0.0052

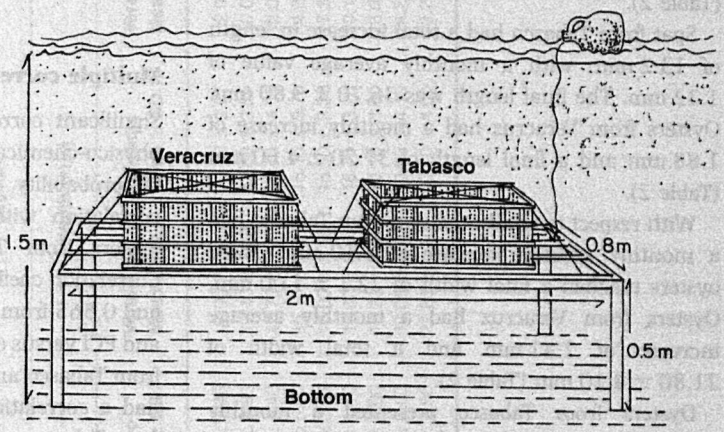

Figure 2 Culture module of three stack boxes of *C. virginica* oyster from Veracruz and Tabasco.

Culture system

One module of three stack boxes was used for each population: 200 oysters in the lower box were used to determine growth, and 150 oysters from the upper box were used to determine PCI. A third box was used at the top as a cover. The culture module was placed 0.5 m from the bottom on a metal rack, at a depth of 1.5 m (Fig. 2). As it was necessary to have spat within a similar size range, the number obtained from the natural beds for the experiment was small, and no replica for each stock was set up. Each box was considered as an individual population.

System maintenance

The stack boxes were pulled out of the water monthly to eliminate fouling organisms from the boxes and oysters were scrubbed with a plastic brush and rinsed to maintain a free water flow.

Statistical analysis

Test of normality was applied to the initial population data of both stocks, and the Bartlett test was used to determine variance between stocks. At the end of the growth study, the Student's *t*-test was used to determine where there were significant differences in size between stocks. To evaluate the effect of physico-chemical parameters on the growth and condition index a multiple correlation analysis was carried out. Paired *t*-test on the PCI data was carried out to determine significant differences between populations and between months.

Results

Enviromental factors

Water temperature, salinity, chlorophyll 'a', POMS, PIMS, and DO results are shown in Table 1.

Growth

Spat from Tabasco presented a monthly average growth in heigth of 3.09 mm. The highest growth rate was in the period of April to July with 5.0 ± 1.34 mm. Total height was 62.90 ± 6.70 mm. Spat from Veracruz presented a monthly average growth of 4.25 mm. The highest growth rate was found from April to July with 7.40 ± 5.19 mm. Total height was 65 ± 6.80 mm (Table 2).

Spat from Tabasco had a total increase in length of 13.2 mm, with a monthly average value of 1.32 mm. The final length was 36.70 ± 3.80 mm. Oysters from Veracruz had a monthly increase of 1.88 mm and a final length of 37.70 ± 4.60 mm (Table 2).

With respect to width, the spat from Tabasco had a monthly average increase of 1.10 mm. These oysters reached a final width of 22.1 ± 4.00 mm. Oysters from Veracruz had a monthly average increase of 1.41 mm and a total width of 21.80 ± 4.10 mm (Table 2).

Oysters from Tabasco presented a monthly average increase in wet weight of 2.85 g. The lowest increase was presented in October with 1.10 g, while the highest was in the period from December to February with 9.74 g. The final wet weight registered was 33.97 ± 9.95 g. Spat from Veracruz showed a monthly average increase in wet weight of 2.98 g. The highest increase was observed from December to February with 8.46 g and in April with 7.10 g, whereas from October to December the increase was only 1.29 g. These oysters reached a total wet weight of 33.26 ± 7.02 g (Table 2).

Physiological dry condition index

The physiological dry condition index of spat from Tabasco recorded an average value of 4.52% with a maximum value of 6.55% in December and a minimum of 3.00% in July. Oysters from Veracruz showed an average value of 5.96% with a maximum value of 14% in August and a minimum of 1.98% in March (Table 2).

Survival

Oysters from Tabasco showed a survival rate of 55%, while 63% survived from the Veracruz stock (Fig. 3).

Statistical analysis

The normality test applied to the initial data did not show significant differences at 95% probability. The Student's *t*-test also did not show differences between the populations on the growth analysis at the end of the experiment. The paired *t*-test on the PCI data between The populations ($P \leq 0.05$) did not showed significant difference (Table 3), even though a significant difference was detected in the Veracruz population in the months of August and October (Table 4).

Multiple correlation

Significant correlation was not observed between physico-chemical parameters and growth with 95% of probability, whilst the PCI had significant correlation with salinity and chlorophyll 'a' for oysters from Tabasco and Veracruz (Table 5). Correlation coefficient PCI versus salinity was 0.317 and 0.565 from Tabasco and Veracruz, respectively, and PCI versus chlorophyll 'a' was 0.202 and 0.310 from Tabasco and Veracruz, respectively. POMS also had a correlation with this index: 0.243 for spat from Tabasco.

Discussion

C. virginica is a poikilotherm organism occurring over a wide range of temperature from 3°C in Chesapeake Bay, USA (Paynter & Dimichele 1990) to 34°C, in Laguna Atasta, Campeche (Rogers & García-Cubas 1981). *C. virginica* has different physiological races that allow it to tolerate a wide range of salinity and temperatures (Hillman,1964, 1965; Li, Fleming & Stewart 1967; Ahmed 1975). In this study, the maximum temperature registered was 33°C and the minimum 28°C, which is the optimum range for oysters growth (Galtsoff 1964).

Temperature and salinity have a direct effect on growth and reproduction (Galtsoff 1964; Ramírez & Sevilla 1965; Giguère & Poirier 1980). The most favourable salinity range for *C. virginica* is between 14 and 29 p.p.t. (Chipman 1948, in García-Valdez 1987). There are local stocks (Palacios Fest & García

Table 2 Monthly values of mean and standard deviation of growth and PCl of *Crassostrea virginica* stocks from Tabasco and Veracruz cultivated in Rio Lagartos, Yucatán

	Growth									
	Height (mm)		Length (mm)		Width (mm)		Wet weight (g)		PCI (%)	
Month	Veracruz Mean ± SD	Tabasco Mean ± SD	Veracruz Mean ± SD	Tabasco Mean ± SD	Veracruz Mean ± SD	Tabasco Mean ± SD	Veracruz Mean ± SD	Tabasco Mean ± SD	Veracruz Mean ± SD	Tabasco Mean ± SD
March	22.50 ± 5.10	32.05 ± 4.50	19.20 ± 4.96	22.80 ± 3.36	7.90 ± 2.90	10.72 ± 2.67	2.90 ± 1.64	5.53 ± 0.03	1.98 ± 0.66	3.79 ± 2.00
April	37.90 ± 8.60	39.80 ± 6.20	28.20 ± 8.60	26.40 ± 3.90	12.40 ± 3.70	11.80 ± 2.55	10.00 ± 5.13	7.77 ± 2.51	4.23 ± 2.66	4.82 ± 2.45
May	46.62 ± 5.60	42.60 ± 5.60	29.10 ± 4.00	29.70 ± 4.40	13.70 ± 3.10	14.70 ± 4.50	12.08 ± 3.79	12.80 ± 4.34	2.00 ± 0.44	3.50 ± 10.80
June	47.80 ± 7.30	48.60 ± 5.50	29.20 ± 4.00	30.50 ± 5.00	15.10 ± 3.20	15.10 ± 3.70	14.00 ± 4.70	14.37 ± 4.47	4.00 ± 3.11	4.00 ± 2.80
July	52.10 ± 7.00	52.80 ± 5.20	32.00 ±4.00	33.30 ± 3.98	16.00 ± 3.10	15.50 ± 3.30	17.32 ± 4.40	16.72 ± 4.95	3.98 ± 1.11	3.00 ± 0.95
August	55.60 ± 7.00	54.90 ± 6.00	34.50 ± 3.70	34.20 ± 5.10	16.60 ± 3.50	16.70 ± 3.20	20.16 ± 5.40	20.15 ± 7.85	14.00 ± 2.66	5.82 ± 2.22
October	56.70 ± 7.00	57.10 ± 5.90	35.80 ± 4.30	34.60 ± 4.00	18.20 ± 2.90	19.10 ± 3.80	23.00 ± 5.82	21.25 ± 4.78	11.88 ± 2.22	5.83 ± 1.31
December	59.40 ± 9.10	58.30 ± 8.20	35.20 ± 4.70	35.50 ± 5.00	19.00 ± 3.60	19.90 ± 4.10	24.29 ± 7.87	24.31 ± 7.19	7.78 ± 1.33	6.55 ± 0.98
February	65.00 ± 6.80	62.90 ± 6.70	37.70 ± 4.60	36.70 ± 3.80	21.80 ± 4.10	22.10 ± 4.00	33.26 ± 7.02	33.97 ± 9.95	3.78 ± 0.88	3.33 ± 1.00

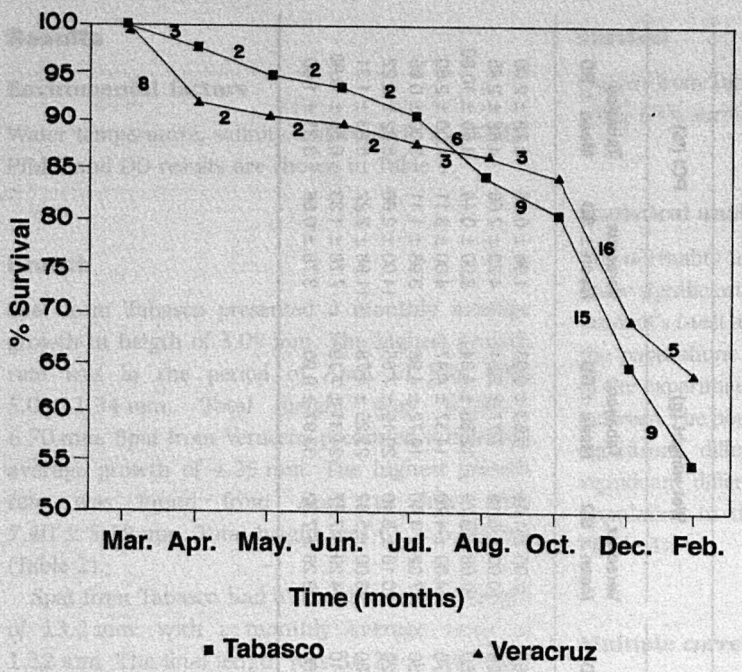

Figure 3 Survival rate, in percentage, of spat from Tabasco and Veracruz during the 10 months of culture.

Table 3 Results from paired *t*-test at 95% of probability for comparison of physiological condition index PCI, shell height and total wet weight from Veracruz and Tabasco oysters. NS indicates no difference found

	N-1	Mean	S^2	t_0	
PCI	8	1.4330	3.4153	1.2678	NS
Height	8	2.5033	17.4734	0.4298	NS
Weight	8	0.0155	0.6862	0.0677	NS

Table 4 Comparison of paired *t*-test by month of PCI with significant difference (95% of probability) for oysters from Veracruz and Tabasco. The asterisk indicates signifficant difference between months, and NS indicates no difference found

Locality	N-1	Mean	S^2	t_0	
Veracruz	35	2.3636	31.7105	2.8093	*
Tabasco	35	0.5461	3.0842	1.8657	NS

1987), which explain the great variation in salinity that oysters can tolerate in different water bodies of the Atlantic and the Golfo de México. In this study, oysters were adapted to the salinity of 30–40 p.p.t., making gonadal maturation, spawning and settlement possible.

The condition index yields a rapid measure of ecophysiological state in the culture of molluscs (Mann 1978; Lucas & Beninger 1985). This index gives important information about the capability of an animal to resist the adverse conditions of the environment by physical, chemical or biological stress (Mann 1978).

Both stocks cultured at Rio Lagartos were similar in growth, however, in PCI, differences were observed in August and October. Soniat, Smith & Brody (1989), in a study of mortality and condition of American oyster in Galveston Bay, Texas, points out that the condition index decreased when the spawing occurred. On the other hand, Martínez, Aldana, Brulé & Cabrera (1995), working with *C. virginica* spat from Estero Pargo, Campeche cultivated in two localities: Estero Pargo, Campeche and Rio Lagartos, Yucatán observed that in both stocks the PCI decreased in July. Histological observations of gonadal sections showed that sexual maturity was reached by oysters of both populations, with 50% in stage IV (ripe) and 40% in stage V (spent) for oysters from Estero Pargo, while oysters from Rio Lagartos showed 22% in stage III (developing) and 66% in stage IV (ripe).

In this study, both stocks transplanted at Rio Lagartos had a low PCI value in July, as that

Table 5 Multiple correlation results of enviromental factor versus growth, survival and PCI of *C. virginica* stocks from Tabasco and Veracruz cultivated in Rio Lagartos, Yucatán

Environmental factor	Growth								PCI		Survival	
	Height		Length		Width		Weight					
	Veracruz	Tabasco	Veracruz	Tabasco	Veracruz	Tabasco	Veracruz	Tabasco	Veracruz	Tabasco	Veracruz	Tabasco
Temperature	0.190	0.190	0.197	0.465	0.131	0.067	0.036	0.059	0.136	0.084	0.064	0.071
Salinity	0.226	0.435	0.576	0.239	0.023	0.135	0.028	0.013	0.565	0.317	0.056	0.462
DO	0.023	0.410	0.207	0.380	0.021	0.241	0.003	0.111	0.088	0.053	0.010	0.084
Chlorophyll 'a'	0.001	0.056	0.006	0.141	0.002	0.005	0.011	0.002	0.310	0.202	0.060	0.162
PIMS	0.144	0.114	0.069	0.004	0.084	0.027	0.012	0.070	0.195	0.005	0.322	0.021
POMS	0.131	0.069	0.0003	0.026	0.002	0.028	0.325	0.236	0.104	0.243	0.004	0.070

Table 6 Monthly average growth for *Crassostrea virginica* cultured in differents lagoons along the Golfo de México

Source	Average growth (mm per month)	Culture condition	Site
Aldana-Aranda 1990	7.4	in Nestier boxes on a metal rack	Rio Lagartos, Yucatán
De Lara1972	9.8	-	San András, Tamaulipas
García Valdez 1987	1.6	on the bottom	El Conchal, Veracruz
García Valdez 1987	6.2	in Nestier boxes on suspension	El Conchal, Veracruz
Martínez *et al.* 1995	2.6	in Nestier boxes on suspension	Rio Lagartos, Yucatán
Martínez *et al.* 1995	7.0	in Nestier boxes on suspension	Estero Pargo, Campeche
Palacios Fest 1983	4.4	-	Palo de Leche, Tamaulipas
Palacios Fest 1983	6.0	-	Paso de las Rivas, Tamaulipas

observed by Martínez *et al.* (1995), which could be interpreted as a spawn. The index was very similar in both stocks, although, in August a rise in condition indices was observed, with higher values for oysters from Veracruz. In this month the highest salinity and chlorophyll 'a' values were also recorded. This rise in the PCI is highly correlated to high primary productivity (Table 5), that can be interpreted as a gain in weight by the oysters.

The PCI values observed in this study were from 3.10–6.52% with an average of 4.46% for oysters from Tabasco, and from 1.76–13.89% with an average of 5.76% for oysters from Veracruz. These results were lower than those registered in 1987 by García Valdez in Laguna Mandinga, Veracruz (5.99–11.29%) and by Aldana Aranda (1990) in Rio Lagartos, Yucatán (3.25–17.28%). However, the PCI values of this work were higher than those recorded by Rainier and Mann (1992) in James River, Virginia, USA (1.8–2.3%) and by Martínez *et al.* (1995) in Estero Pargo, Campeche (1.9–3.6%) and in Rio Lagartos, Yucatán (2–3.6%).

The survival rates of 55 and 63% for oysters from Tabasco and Veracruz, respectively, were higher than those obtained by Palacios Fest (1983) in Tamaulipas (13.37%), and lower than those registered by Aldana Aranda (1990) in Rio Lagartos, Yucatán (70%). During the first month after transplantation of the oysters from the two localities to Rio Lagartos, a mortality of 3 and 7% was observed for oysters from Tabasco and Veracruz, respectively. These can be explained as transfer stress (Mackenzie 1981). The mortality was higher in spat from Veracruz and there are two possible reasons: the distance from Veracruz is further than Tabasco and the spat were smaller than those at Tabasco. The growth was regular from the beginning (March) to the end of the experiment. It is common to observe an inhibition of growth after transplantation; however, in this study it was not detected. The PCI values increased during the first month, which showed that there was a good adaptation of the oysters to the new site. In this site, Aldana-Aranda (1990) observed a high activity of primary production in the period of March–April: 82.1 mg $C\ m^{-3}\ h^{-1}$ with a respiration value of 56.4 mg $C\ m^{-3}\ h^{-1}$ at a temperature of 28°C and salinity of 34 p.p.t. The higher mortality was observed in December with a value of 15% in both populations and in February with 5 and 9% for Veracruz and Tabasco, respectively. One possible explanation to these results could be the effect of a long exposure of the oysters to a high salinity.

Although spat from Veracruz and from Tabasco are geographically separated by a considerable distance ($\approx$ 1000 km), oysters from both places are genetically similar. This similarity was observed by Soegono (1991) in a genetic variability study, along the Mexican coast of the Golfo de México. Oysters from Veracruz were used for many years to supply the culture bed in Mecoacán, Tabasco, which explains the close similarities between the two stocks and the results in growth (Table 2) confirmed by the Students *t*-test which shows no significant difference between stocks ($P = 0.05$). Growth values for *C. virginica* along the Golfo de México obtained by others authors are summarized in Table 6.

Oyster culture of *C. virginica* is possible with the transplantation of spat into Rio Lagartos, Yucatán. The oyster growth was regular for both stocks and survival rates were acceptable. Physical and chemical environmental parameters are acceptable for the culture of bivalve molluscs in this area.

Acknowledgments

This research was supported by grants: DGXII-CII*0432 ME (JR) from European Economic Community, P65000 ME from Science and Technology Council of the French Embassy, C88013 from Government of Yucatan and Grant no. 57191 of CONACyT Mexico. The authors are grateful to Erick Baqueiro Cárdenas and Victoria Patiño Suárez for their help with the English revision. Line drawings were made by Héctor Mares. The authors also thank the fishermen of Rio Lagartos for their help.

References

Abbott R.T. (1974) *American Seashells*, 2nd edn. Van Nostrand Company Inc. New York.

Ahmed M. (1975) Speciation in living oysters. *Advances in Marine Biology* **13**, 375–397.

Aldana Aranda D. (1990) Crecimiento del ostión americano *Crassostrea virginica* Gmelin (1971) en la Ría de Río Lagartos, Yucatán, México. *Memorias del VIII Simposium de Biología Marina*, (ed. by M. Dailey & H. Bertsch), pp. 36–50. Ensenada, Mexico.

Boyd C.E. (1981) *Water quality in warmwater fish ponds*. Alabama Agriculture Experimental Station, Alabama University.

Cordero F. (1988) *Las Lagunas costeras mexicanas*, 2nd edn. Centro de Ecodesarrollo, Secretaría de Pesca.

De Lara A.R. (1972) *Evaluación de los recursos ostrícolas de las lagunas Mecoacan – Machona – Carmen, Tabasco*. Tesis Profesional, Facultad de Ciencias UNAM, 32 pp.

FAO Fishery Information, Data and Statistics Services (1992) Aquaculture production 1984–1990. *FAO (Food and Agriculture Organization of the United Nations) Fisheries Circular No. 815 Revision 4*. 205 pp.

Galtsoff P.S. (1964) The American oyster *Crassostrea virginica* Gmelin. *U.S. Fish Wildlife Service Fisheries Bulletin*, 64.

García Valdez D.P. (1987) *Crecimiento de C.* virginica *cultivado en suspensión en el estero de El Conchal del sistema lagunar Boca del Río-Mandinga, Veracruz*. Tesis Profesional ITMAR, Boca del Río, Veracruz. 93 pp.

Giguère M. & Poirier L. (1980) Essais d'élevage de l'huître Américaine *C. virginica* (Gmelin), dans les Saint Laurent. *Travaux Sur Les Pêcheries du Québec* **47**, 29.

Hillman R.E. (1964) Chromatographic evidence of intraspecific genetic differences in the eastern oyster *Crassostrea virginica*. *Systematic Zoology* **13**, 12–18.

Hillman R.E. (1965) Chromatographic studies of allopatric populations of the eastern oyster *Crassostrea virginica*. *Chesapeake Science* **6**, 115–116.

Li M.F., Fleming C. & Stewart J.E. (1967) Serological differences between two populations of oysters *Crassostrea virginica* from the Atlantic coast of Canada. *Journal of the Fisheries Research Board of Canada* **24**, 443–446.

Lucas A. & Beninger P. (1985) The use of physiological condition indices in marine bivalve. *Aquaculture* **44**, 187–200.

MacKenzie C.J. Jr. (1981) Biotic potential and environmental resistance in the American oyster (*Crassostrea virginica*) in Long Island Sound. *Aquaculture* **22**, 229–268.

Mann R. (1978) A comparison of morphometric, biochemical and physiological indices of condition in marine bivalve molluscs. In: *Energy and Enviromental Stress in Aquatic Systems*. (ed. by Thorphe J.H. & Gibbons I.W.), I.W. DOE Symp. Ser. **48**, 484–497.

Martínez I., Aldana D., Brulé T & Cabrera E. (1995) Growth and sexual maturity of American oyster spat: *Crassostrea virginica* (Gmelin, 1791) (Mollusca: Ostreidae), in Yucatán, México. *Avicennia* **3**, 61–75.

Palacios Fest M.R. (1983) *Experimentación al semicultivo de ostión* Crassostrea virginica, *en la Laguna de San Andrés, Tamaulipas. México*. Tesis Profesional, Facultad de Ciencias. UNAM, México. 118 pp.

Palacios Fest M. & García S.S. (1987) *Manual técnico para la operación de Centros Acuícolas Productores de Ostión*. Comité Coordinador para la operación Acuícola. Secretaría de Pesca, México, 342 pp.

Paynter K.T. & Dimichele L. (1990) Growth of tray-cultured oyster *Crassostrea virginica* (Gmelin) in Chesapeake Bay. *Aquaculture* **87**, 289–297.

Rainier J.S. & Mann R. (1992) A comparison of methods for calculating condition index in eastern oysters, *Crassostrea virginica* (Gmelin, 1791). *Journal of Shellfish Research* **11**, 55–58.

Ramírez G.R. & Sevilla M.L. (1965) Las ostras de México. Datos biológicos y planeación de su cultivo. *Publicaciones segunda época*. **II**, 4–11.

Rogers N.P. & García Cubas A. (1981) Evolución gonádica a nivel histológico del ostión *Crassostrea virginica* (Gmelin) del sistema fluvio-lagunar Atasta-Pom, Laguna de Términos, Campeche, México. *Anales Instituto de Ciencias del Mar y Limnología. UNAM* **8**, 21–42.

Soegono D. (1991) *Caractéristiques génétiques de populations d'huîtres tropicales:* Crassostrea et Saccostrea. Thèse de Doctorat d'Université de Bretagne Occidental, Brest, Francia. 102 pp.

Soniat T.M., Smith L.E. & Brody M.S. (1989) Mortality and condition of American oyster in Galveston Bay, Texas. *Contributions in Marine Science* **31**, 77–99.

Strickland J.D.H. & Parson T.R. (1972) *A practical handbook of seawater analysis*. Fisheries Research Board of Canada, Ministry of Fish. Ottawa.