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Article *in* Journal of Shellfish Research · January 1994

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Journal of Shellfish Research, Vol. 13, No. 2, 503–505, 1994.

SURVIVAL, GROWTH, AND GLYCOGEN CONTENT OF PACIFIC OYSTERS, *CRASSOSTREA GIGAS* (THUNBERG, 1793), AT MADEIRA ISLAND (SUBTROPICAL ATLANTIC)

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ABSTRACT Pacific oysters, *Crassostrea gigas,* were introduced to Madeira Island (subtropical Atlantic) and grown at depths of 10 to 25 m. There were no significant differences between oysters grown at 10, 15, and 25 m depth for any of the parameters analyzed. Live weight and shell size increased significantly, whereas dry meat weight and condition declined significantly by 45 and 70%, respectively. Glycogen content decreased by 90% within 5 weeks; this was not linked to gametogenesis. Overall mortality attained 73% in 5 months. The oysters' poor performance is attributed to a combination of stress factors.

KEY WORDS: bivalve, oyster, *Crassostrea,* introduction, aquaculture, condition

INTRODUCTION

The Pacific oyster, *Crassostrea gigas* (Thunberg), is being grown with commercial success in a variety of environments worldwide. In temperate zones, its growth decreases in winter (e.g., Askew 1972, Héral and Deslous-Paoli 1991), but under subtropical conditions, continuous growth can be achieved during the entire year (e.g., Hughes-Games 1977). At Madeira Island, water temperatures are favorable at 17 to 23°C year around. Oysters (*Ostrea* species) have been found occasionally (Abreu, personal communication), but there has never been any local fishery or culture. A small-scale grow-out trial with imported Pacific oysters, however, led to encouraging results (Waschkewitz, personal communication) and motivated this present study.

MATERIALS AND METHODS

Healthy half-grown oysters, *C. gigas,* of British origin, that had been grown in Flensburg Fjord (Western Baltic) from spat size, were introduced to Madeira at a mean live weight of 9.6 g. They were grown at 10, 15, and 25 m depth in six lantern nets with 1 cm mesh that were anchored at a depth of 27 m in a small bay near Funchal Harbour. Each net was stocked with about 320 oysters, at a density of less than 1 g cm^{-2} (as recommended by Spencer 1990).

Every 2 or 3 weeks from July until December 1991, the water temperature at the site was determined and 30 oysters from each depth were sampled randomly by SCUBA diving. Dry weight was determined after drying for 24 h at 60°C, and ash weight was determined after incineration for 24 hours at 550°C. Glycogen was determined after Keppler and Decker (1984); pieces of mantle tissue of about 100 mg were excised from six randomly selected live oysters in each sample, stored in micro-test tubes at −60°C, and later transported on dry ice to IfM Kiel for analysis. To assess the oysters' overall performance, the condition index (CI) of Lawrence and Scott (1982), recommended by Bodoy et al. (1986) and Crosby and Gale (1990), was calculated as: CI = (dry meat weight × 1,000)/(live weight − dry shell weight).

RESULTS

Sea water temperature varied between 24°C in August and September and 19°C in December. There were no significant differences between oysters grown at all three depths (Mann-Whitney *U* test, 0.95 level), and the results for 15 and 25 m have been pooled; the lantern nets at 10 m disappeared 8 weeks after the beginning of the experiment and have been excluded from further analysis.

There was an increase in live weight and shell size and a simultaneous decrease in dry and ash-free dry meat weight of the

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TABLE 1.

Growth (mean ± standard deviation) and mortality of oysters (*C. gigas*) during grow out at Madeira Island. Pooled data for oysters grown at 15 and 25 m depth. N = 60 (week 21, N = 30).

Weeks in Culture	Shell Height (mm)	Live Weight (g)	Wet Meat Weight (g)	Dry Meat Weight (g)	Ash-Free Dry Meat Weight (g)	Dry Shell Weight (g)	Cumulative Mortality (%)
0	41 ± 3	9.6 ± 1.7	2.4 ± 0.6	0.37 ± 0.14	0.31 ± 0.13	5.5 ± 1.1	
7	43 ± 4	10.4 ± 1.8	2.2 ± 0.5	0.23 ± 0.08	0.16 ± 0.07	5.8 ± 1.1	39
14	47 ± 6	12.6 ± 3.3	2.5 ± 0.7	0.23 ± 0.07	0.15 ± 0.05	7.6 ± 2.1	55
21	47 ± 6	13.5 ± 4.0	2.4 ± 0.8	0.20 ± 0.06	0.12 ± 0.04	7.8 ± 2.4	73

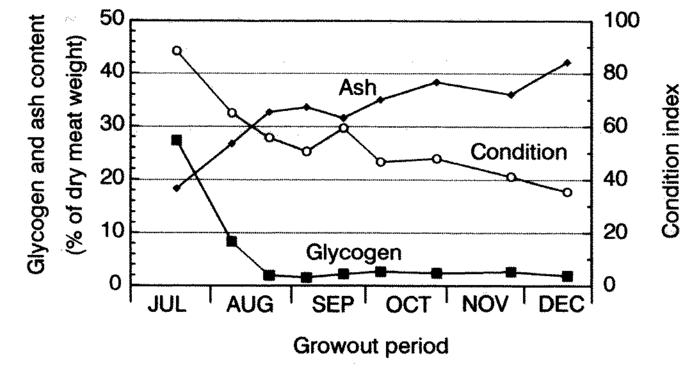

Figure 1. Glycogen and ash levels (left scale) and condition index (right scale) in oysters (*C. gigas*) during grow out at Madeira Island. Pooled data for oysters grown at 15 and 25 m depth. N = 12 for glycogen; N = 60 for ash and condition index (except December, where N = 6 and N = 30, respectively).

oysters during the rearing period; wet meat weight remained constant. The mortality exceeded 70% (data summarized in Table 1). The ash content of the meat increased insignificantly in absolute terms, but it more than doubled as a percentage of the dry meat weight. The condition index and the glycogen level in the meat declined, respectively, to less than 40% and less than 10% of the initial values (Fig. 1).

DISCUSSION

We have no indications that the stock might have been diseased, nor has there been any record of disease or mortality in the original Baltic stock in the years before, during, or after the introduction to Madeira (the source of the oysters was once intended as a quarantine station for imports to Germany). The oysters' initial condition index was in the normal range, and the values found at the end of the experiment are not unusually low (cf. Table 2), except that they did not result from spawning activity.

Oysters are usually cultured in the intertidal zone or in shallow depths, but cultivation at depths of 10 m and more is often advantageous (Marteil 1979); we have not found any reports on oyster cultivation at 15 to 25 m, but the absence of any depth correlation in our data makes negative effects seem unlikely.

The temperature and salinity stress brought about by the transfer from the Baltic to Madeira can by itself hardly account for the oysters' poor performance. It brought an increase in salinity (by 15 to 20 ppt) and in temperature (by about 5°C) for the oysters. Oysters from the identical Baltic stock were, however, subjected to the same stress by Waschkewitz and performed better. Salinities at Madeira are high (36 to 37 ppt year around; INIP 1982), but Hughes-Games (1977) obtained excellent growth of *C. gigas* at 42 ppt and at summer temperatures of 20 to 34°C.

TABLE 2.

Comparison of condition (determined after Lawrence and Scott 1982) in oysters (*C. gigas* and *Crassostrea virginica*).

Source	High Values	Low Values	Remarks
Lawrence and Scott (1982)	61	41	*C. virginica;* sampled Jan.–June
Bodoy et al. (1986)	60–120	20–30	*C. gigas;* 4-year study of 21 condition indices
Crosby and Gale (1990)	79–88		*C. virginica;* sampled in May–June
This study	90	35	*C. gigas;* sampled July–Dec.

The facilities and equipment available for this investigation were insufficient for the analysis of phytoplankton and nutrients, but the waters of Madeira are oligotrophic (Chl. values of 0.05 to 0.15 mg m^{-2}; INIP 1982), and starvation may have been an important additional stress. In a 6-month starvation experiment with *C. gigas*, Riley (1976) also found an important decline in dry meat weight; carbohydrate levels declined more than lipid and protein, but in the mantle (its main storage site), carbohydrate declined only from 28 to 23% (28 to 2% glycogen in this study). Seaman (1991) kept oysters from the same stock without food for a similar period of time with similar results as Riley (cf. Table 3).

The steep decline in glycogen content that followed the oysters' transfer to Madeira was not associated with gametogenesis. This indicates that the animals were more stressed than in the examples cited above and were thus forced to consume their reserves entirely (cf. Gabbott 1983). We think that the oysters' poor performance resulted from high metabolic demand (due to salinity and temperature stress) in combination with nutritive stress. Better results might be obtained if the oysters were introduced at another time of year, as had been the case with Waschkewitz' introduction.

ACKNOWLEDGMENTS

We thank R. Waschkewitz (Caniço, Madeira) for financial and material support, the Direcçao Regional da Agricultura for the use of its laboratory facilities at Camacha (Madeira), and H. Rosenthal, R.-A. Vetter, and R. Saborowski (IfM Kiel) for discussions and for help with the glycogen determination.

TABLE 3.

Performance of oysters (*C. gigas*) after 20 to 25 weeks of starvation, as compared with this study.

Source	Duration of Experiment (Weeks)	Decline in Meat Weight (% of Initial Value)	Decline in Carbohydrate[a] (% of Initial Value)		Cumulative Mortality (%)	Remarks
			Mantle	Whole Body		
Riley (1976)	25	39	20	38	40	Starvation at 13.5°C
Seaman (1991)	20	30		20–40	20–48	Air storage at 7°C
This study	21	46	93		73	Same stock as Seaman (1991)

[a] Total carbohydrate in Riley (1976); glycogen in Seaman (1991) and in this study.

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