Indian Journal of Marine Sciences
Vol. 9, December 1980, pp. 258-262

Size Related Predictions of Meat Growth & Yield in Reef Oysters from the Mississippi Sound

R V KRISHNAMOORTHY*, G J LAKSHMI, PATRICIA BIESIOT & A VENKATARAMIAH
Gulf Coast Research Laboratory, Ocean Springs, Mississippi 39564, USA

Received 17 *March* 1980; *revised received* 16 *June* 1980

Meat weight versus shell length relationship in oysters, *Crassostrea virginica* (Gmelin), was established during 4 seasons of the year for males and females separately. During the seasons tested, males and females exhibited polynomial increase in meat mass as the shell length increased. Oyster meats increased in mass from October to April but wasted away from April to October. Sex influences were seen with males gradually losing weight for a longer duration than females. Data on meat weight per unit length revealed variations in absolute weight or heaviness of the oyster meat. Females were heavier but the degree fluctuated depending on shell length and season. Small males (30 mm) were heavier from July to October while females of the same size were heavier from October to April.

Relationship of shell length to meat weight of molluscs has received considerable attention and is used to set minimum size limits for the harvest of natural populations[1-3]. Analysis of shell length versus meat weight has been done for 3 species of bivalves[4-8] and 4 species of gastropods[7]. Apparently no such information on oysters from the Mississippi Sound is available. Earlier studies[8] with 'lean' oysters from the Mississippi Sound have indicated that the shell length and meat weight relationship varies with sex. The present paper describes seasonal variations in this relationship. The objective of the study is to propose predictive models for relative meat growth to account for seasonal meat yields of oysters from natural reefs.

Materials and Methods

Oysters *Crassostrea virginica* (Gmelin) (15 to 150 cm shell length) were collected from the Bay of St Louis, Mississippi during Oct 1977 and Feb, April and July 1978. After removing the shell in the laboratory, oyster meat was blotted dry and weighed. Length of the left valve was measured. Sexes were distinguished from gonadal smear.

Shell length and meat weight relationship were plotted sexwise for each season on cm-square graph paper. Non-linear regression lines were drawn from the raw data using an 1130 IBM sub-routine package. Regression models were tested and evaluated for growth rate considerations.

Proportionality constants for non-linear relationship of meat weight and shell length were determined for each season using the function of Ivlev[9]. Relative meat growth rate between seasons for an individual size was calculated using an exponential equation[10,11].

Meat weight per unit length (M/L) ratio was calculated for each oyster and plotted against shell length. Regression analysis was done for these data using the least squares method. Variations in M/L ratio indicate the changes in meat mass and generalize the overall changes in biomass with reference to shell length. Variation between any 2 seasons would indicate the change in meat content yield between those seasons. The ratios were evaluated for different shell lengths from the regression equations and inter-seasonal meat yields were calculated.

Results

Meat weight and shell length relationship varied with season in *C. virginica* (Fig. 1). The realtionship was non-linear during all seasons and followed a polynomial function with an increase in meat mass as the shell length increased. The curves resembled those obtained for other molluscs[4-7]. Sex could be differentiated during winter when the gametes were not developed. Regression analysis of data (Fig. 1) gave a fairly significant correlation. Regression equations presented here serve as models to predict meat mass for various sizes (shell lengths) of male and female oysters which differed in curvilinear slopes only in the fall (Fig. 1a) where males exhibited a more exponential meat growth rate than females.

The proportionality constants (α) differed distinctly during different seasons (Table 1). Higher α values suggest that the oysters had greater accumulation of

*Visiting Scientist from the Department of Zoology, University of Agricultural Sciences, Bangalore 560065, India.

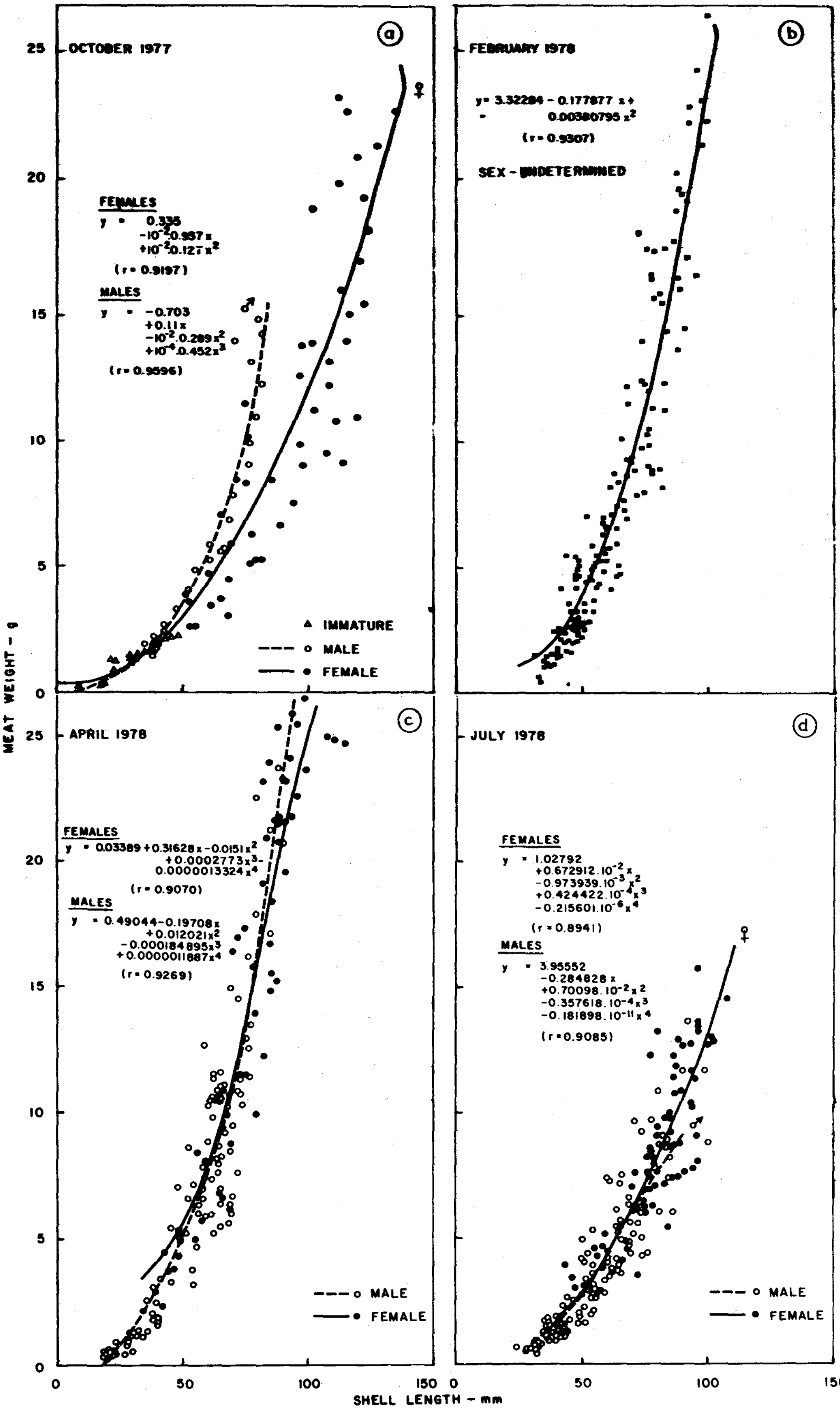

Fig. 1—Shell length and meat weight relationship in *C. virginica* [Harvested in a, Oct 1977 (sal. 11.6‰, temp. 18 C); b, Feb 1978 (sal. 18‰, temp. 15.5 C); c, April 1978 (sal. 14‰, temp. 21°C); and d, July 1978 (sal. 17‰, temp. 31 C)]

meat to attain maximum size. Theoretically, a higher α indicates that the animals are capable of reaching maximum weight at lower sizes (shell length)[9]. Meat mass accumulation in the population was evidently more during winter than the other months tested. Males showed a lower α in spring (April) indicating a low meat content while females showed low meat weight in the fall.

Theoretical instantaneous growth rate (G) values indicated that meat growth was related to size, sex, and season (Table 2). Growth rates were obviously extreme. A few generalizations can be made from these data. Females, regardless of size, showed the greatest meat growth rate from October to April but from April to July they lost weight. Females of 40-60 mm shell length also lost weight from July to October but at a relatively lower rate than earlier in the year. On the other hand, males below 30 mm shell length lost weight from February to April while larger ones lost weight from April to July. Interestingly, males of medium legal size (76 mm) showed growth of meat during July to October while females of that size lost weight.

Analysis of M/L ratios indicates variations in degree of plumpness of oysters in relation to sex and season (Table 3). Figs 2a and b illustrate the relationship of these ratios to varying shell length. Seasonal variations in the relationships are obvious. Females were fat from October to April and lost most weight from April to July. Most males were fat from July to October although smaller-sized males lost weight from October to February. In general, females showed greater weight per unit length than the males.

Table 1—Variations in Proportionality Constant (α) for the Meat Weight and Shell Length Relationship of *C. virginica* during Different Seasons

Season	Male	Female	Indeterminate
Fall	0.6261	0.3576	
Winter			0.7787
Spring	0.2959	0.7767	
Summer	0.7210	0.5370	

Table 2—Relative Meat Growth Rates (G) of *C. virginica* (calculated from initial and final meat weights obtained from regression analysis of seasonal data)

Shell length (mm)	Female growth rates mg/day				Male growth rates mg/day			
	A	B	C	D	A	B	C	D
10	16.8	−0.5	−7.8	−10.6	4.8	−6.3	2.2	−0.2
20	6.5	7.8	9.5	−4.9	5.5	−7.6	3	−0.7
30	1.6	6.5	−7	−1	1.2	−0.4	−7.4	4.9
40	1.3	2.9	−5	0.4	1.3	3.6	−8.8	2.9
50	2.5	1.6	−5.3	0.5	1.8	3.1	−7.4	1.6
60	3.6	1.8	−6.5	0.1	1.7	2.0	−6.5	3.4
70	4.6	2.3	−7.6	−0.4	1.2	1.6	−6.9	3.1
80	5.3	2.4	−8.3	−0.7	0.4	2.0	−8.7	5
90	5.9	1.9	−8.4	−0.8	−0.4	5.7	−14.1	7.2
100	6.5	0.7	−8.1	−0.6				
110	6.8	1.6	−5.7	−1.2				

A = Oct to Feb; B = Feb to April; C = April to July; D = July to Oct.

Table 3—Seasonal Changes in Relative Theoretical Meat Weight Per Unit Length of *C. virginica* (obtained from the regression analysis of M/L data)

[Negative value indicates the reduction in meat mass]

Oyster shell length (mm)	Female mg meat/mm shell length				Male mg meat/mm shell length			
	A	B	C	D	A	B	C	D
20					−44.8	−4.8	49.2	0.3
30					−38.3	−3.5	10.9	30.2
40	−8	−2.8	7.7	3.1	−16.4	−2.4	12.3	6.5
50	16.8	6.2	−20.3	−2.7	−19.1	−1.1	−3.8	24
60	39.6	15.2	−37.6	−17.2	−9.6	0.1	−14.9	24.4
70	60.5	24.2	−59.7	−25	0	1.4	−21.2	19.8
80	79.3	51.2	−94.5	−18	9.6	2.6	−22.5	10.3
90	96.2	42.2	−119.2	−19.2	19.1	3.8	−18.8	−4.1
100	11.1	51.2	−144	−18.2				
110	123.8	60.2	−143.8	−48.2				

A = Oct to Feb; B = Feb to April; C = April to July; D = July to Oct.

Discussion

Majority of earlier work dealt with instantaneous growth estimates of whole oysters on an experimental time scale[12-14], which reported seasonal fluctuations in the growth rate of oysters provided with natural food and attributed it to fluctuations in seasonal water temperature changes. Based on the observed relationship of temperature and food availability on growth, MaLouf and Breese[11] suggested that under ideal conditions maximum growth of immature Pacific oysters might be achieved at temperatures approaching 20°C. Present data for *C. virginica* suggest that seasonal fluctuations in meat growth are dependent on the shell size (age) of the oyster. Seasonal meat growth rates are high in immature oysters (40 mm) while significant decreases in meat bulk for the size range of 40-60 mm shell length were noticed in spring (April-July). Fluctuations in seasonal meat growth are also related to sex and are due to the production of gametes and reserve products including glycogen. The loss of meat in males was observed to be of longer duration than in females (Table 3), possibly due to gradual release of spawn over a longer period of time.

The instantaneous growth rate (G) could easily be applied to population studies[15-19]. Dame[12] calculated G values for 5 sizes of *C. virginica* from Clambank

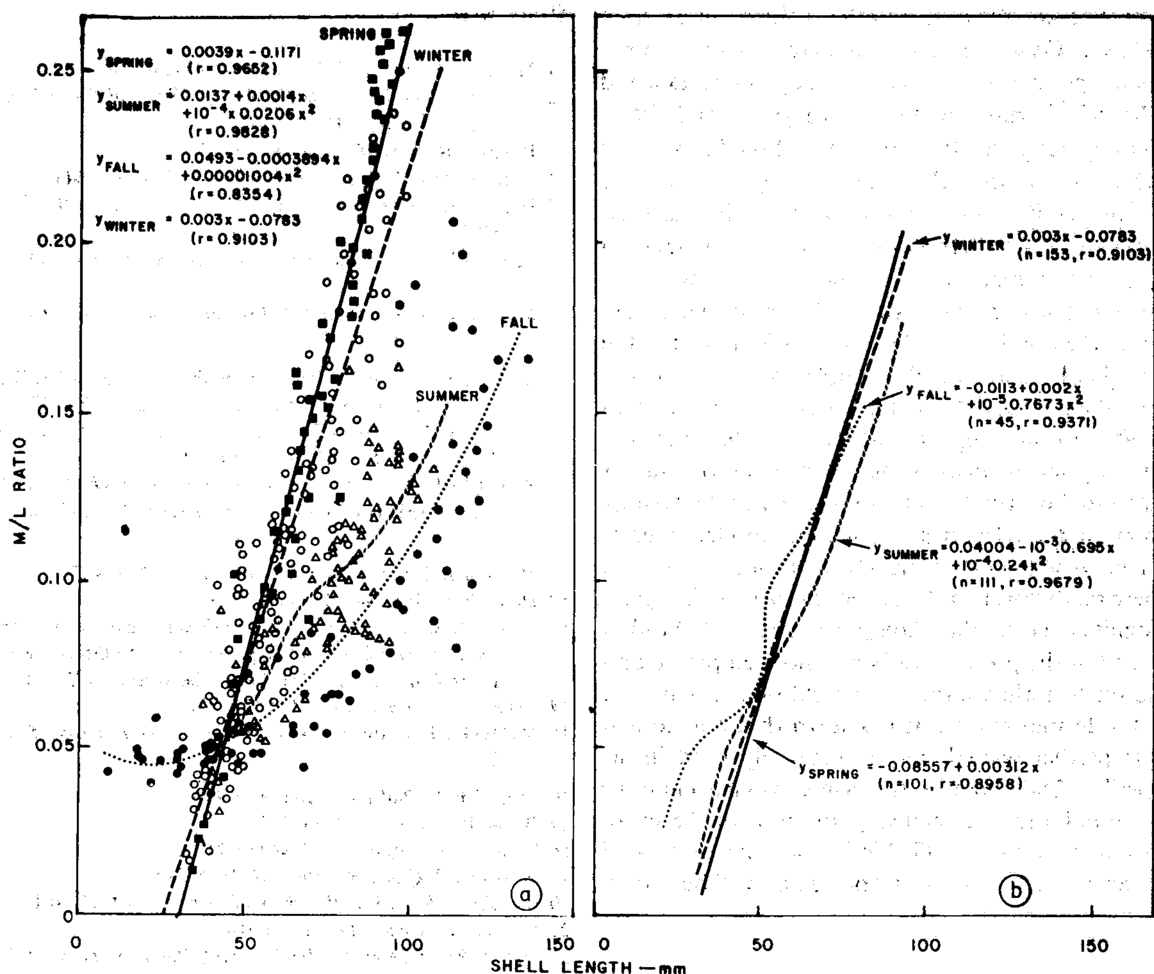

Fig. 2—Seasonal variation in meat weight per unit length of (a) female and (b) male *C. verginica* in relation to shell length [Season refers to oysters collected in months indicated in Fig. 1]

Creek, North Inshore, Georgetown, South Carolina and found besides seasonal variations the existence of size-related growth rates for oysters. On a whole weight basis he found that the rate decreased with increasing size and that the maximum G for adult oysters was in fall after the peak environmental temperature.

Present data, derived from the meat weight-shell length models, suggest that no size relationship exists intra-seasonally with reference to meat growth; but between seasons that meat growth varies with size. Shells grow actively in oysters until they reach marketable size[20] and whole animal weight growth is probably size-related. Based on length, growth rate of *C. virginica* varies according to year and area. For example, oysters found attached to templates off Texas and Louisiana grow at rates of 5.1 to 8.1 mm/month[21]. Oysters in suspension culture from a petroleum platform off the Texas Coast[22] grew at rates of 1.2 to 1.4 mm/month. Ingle and Dawson[23] predicted oyster shell growth to be approximately 2 mm/month in Florida waters. Hofstetter *et al.*[24] reported different rates for different years for oysters from 2 reefs in Galveston Bay; the rates were 3.7 mm/month during 1963; 1.4 mm/month during 1965 in Switchover Reef and 0.5 mm/month during 1963 and 1.9 mm/month during 1965 in Hanna's Reef.

Depth does not appear to affect the growth[22] nor the time of spawning[25]. However, such generalizations seem to be uncomprehensive as growth rates are dependent on many factors. *Ostrea edulis* and *C. gigas* grow well from April to October and their instantaneous growth rates decrease with age on a whole weight basis[13]. Orton[26] observed a pause or cessation of shell growth during the summer which was associated with spawning. Walne[27] argues that oyster shell growth is continuous through out the year. Meat growth seems to be different. The meat content of *C. virginica* in Mississippi Sound increases from October to April and decreases from April to October.

Meat yields in oysters are assessed differently[28]. A widely used index is the condition index, a factor which denotes the per cent dry meat weight per unit volume of the shell cavity[12]. According to Quayle[28] this is not a correct assessment as it denotes volume more than actual meat. Oyster processors also refer to the number of oysters per gallon as a measure of yield. Rockwood and Mazek[29] analysed data of 16 yr (from 1959 to 1975) of oyster yields from the unpublished records of the NOAA statistical collection agent for the Apalachicola Bay area and found that the seasonal changes in yield paralleled seasonal changes in atmospheric temperature; higher yields were associated with lower temperatures. Their estimates were based on the number of gallons of shucked meat to the four-bushel Florida barrel of whole oysters. Quayle[28] suggested another statistical procedure to obtain meat yield after establishing its relations with the condition factor of oysters in an area. He related condition factor and production (in gallons) of oysters in Ladysmith Harbour and fitted a linear model. This model suggests that meat yield increases linearly with condition factor. All these models were not size specific. Size of the oyster has significance in the cholesterol content[8]. Models described in the present study are more empirical and predictive to estimate the meat yield of a specific size and at a desired season. It is known that polynomial models predict growth more accurately than linear models[30,31]. Data on M/L ratios in *C. virginica* indicate the seasonal and size-related plumpness of the meat. The data demonstrate (Table 3) that the oysters of above legal size are fattest in spring and will be lean in fall.

Acknowledgement

The authors are indebted to Mr Alfred Chestnut for collection and sexing of oysters. Thanks are due to Dr Gordon Gunther for his review of the manuscript. Thanks are also due to Mr John Ogle for his aid in literature collection, to Mr Don Watson for illustrations, to Mr David Boyes for his assistance in computations of data and to Ms Sharon Wilson Christmas for secretarial assistance.

References

1 Medcof J C, *Bull Fish Res Bd Can*, **44** (1949) 6.
2 Baird F T (Jr), *Marine Department of Sea and Shore Fisheries Maine Res Bull*, **16** (1954) 3.
3 Hayes E B, *ICMAF Bull*, **3** (1966) 17.
4 Feder H M & Paul A J, *Proc natn Shellfish Ass*, **64** (1974) 45.
5 Hidu H, Richmond M S & Price A H, *Proc natn Shellfish Ass*, **67** (1977) 75.
6 Feder H M, Paul A J & Paul J, *Proc natn Shellfish Ass*, **66** (1976) 21.
7 MacIntosh R A & Paul A J, *Proc natn Shellfish Ass*, **67** (1977) 103.
8 Krishnamoorthy R V, Venkataramiah A, Lakshi G J & Biesiot P, *Proc World Mariculture Society*, **9** (1978) 567-576.
9 Ivlev V S, *Experimental ecology of the feeding of fishes* (Yale Univ. press, New Haven) 1961, 302.
10 Ricker W E, *Methods for assessment of fish production in fresh waters*, IBP Handbook No. 3 (Blackwell's, Oxford) 1968, 313.
11 MaLouf R E & Breese W P, *Aquaculture*, **12** (1977) 1.
12 Dame R F, *Mar Biol*, **17** (1972) 243.
13 Maurer D & Aprill G, *Feasibility study of raft culture of oysters in the Delaware Bay area* (Rep. submitted to Delaware River Basin Comm, Univ Del, Lewes Delaware) 1973, 180.
14 Askew C G, *Aquaculture*, **1** (1972) 237.
15 McHugh J L & Andrews J D, *Proc natn Shellfish Ass*, **45** (1955) 217.
16 Dehnel P A, *Biol Bull*, **110** (1956) 43.
17 Bayne B L, *Ophelia*, **2** (1965) 1.
18 Dehnel P A, *Physiol Zool*, **28** (1955) 115.
19 Korringa P, *Quart Rev Biol*, **24** (1955) 266.
20 Galtsoff P A, *Fish Bull Fish Wildl Serv US*, **64** (1964) 1.
21 Gunter G, *Science*, **113** (1951) 516.
22 Ogle J, Ray S M & Wardle W J, *Gulf Res Reports*, **6** (1977) 31.
23 Ingle R M & Dawson C E, *Bull mar Sci Gulf Carrib*, **2** (1952) 393.
24 Hofstetter T P, Heffernan T L & King B D, *Texas Parks and Wildl Dept, Coastal Fish Proj Rep*, **7** (1965) 119.
25 Loosanoff V L & Engle J B, *Biol Bull*, **82** (1942) 413.
26 Orton J H, *J mar Biol Ass UK*, **15** (1928) 365.
27 Walne P R, *J mar Biol Ass UK*, **37** (1958) 591.
28 Quayle D B, *Bull Fish Res Bd Can*, **169** (1969) 193.
29 Rockwood C E & Mazek W F, *Bull mar Sci*, **27** (1977) 34.
30 Dame R F, *Contributions in Marine Sciences*, **19** (1975) 107.
31 Mead R, *J Ecol*, **59** (1971) 215.