MODELISATION OF OYSTER SHELL GROWTH AT 3 STATIONS IN THE PATUXENT RIVER (CHESAPEAKE BAY).

by

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In oyster production area the determination of the stock, estimation of mortality and growth rates are determinant for knowledge of the fishery. Growth models can be used to predict the time to reach marketable size (76 mm in Chesapeake Bay). They are also important in term of management, when they can predict the future value of the stock (Askew, 1978).

Oyster growth models can be built by analysing growth of natural oysters but absolute age is often unknown.

Many authors report growth data in Chesapeake Bay for suspended oyster culture. Unfortunalely, modelisation of the growth was not developed.

In that study oyster, shell growth models have been established at three stations in the Patuxent river. Seasonal effects on growth were integrated in the model.

MATERIALS AND METHODS

From July'89, an off-bottom culture in trays was performed at three stations in middle Chesapeake bay. CBL's Pier station is located in front of CBL at Solomons Island. Green Holly Pound at the mouth of Patuxent river and Benedict Bridge station in the upper Patuxent. These three stations illustrate different hydrological and seasonal trends in environmental conditions and all are located in the vicinity of natural oyster bars. At each station, three densities and two depths were tested for growth rate. Figure 1 shows the arrangement of the off-bottom oyster facility. Each of the suspensories held two trays,one at 1 m below the water surface and the other at 1 m above the bottom. Densities were 220,360 and 660 oysters/m^2. At CBL's Pier station,one tray with marketable size oysters and two trays with spat size oysters (surface and bottom) were added. Trays consisted of round plastic frames (approximately 0.10 m high and 0.25 m^{-2} area). Over the study period, the same 30 animals were collected from the trays, measured for length and returned into the tray. Length means are computed for each group.

Shell oyster growth follows a general Von Bertalanffy growth function :

$$\mathbf{Lf} = Linf\,[1 - \exp\,(-\,K\,(\mathbf{t} - t_o))]\ (1)$$

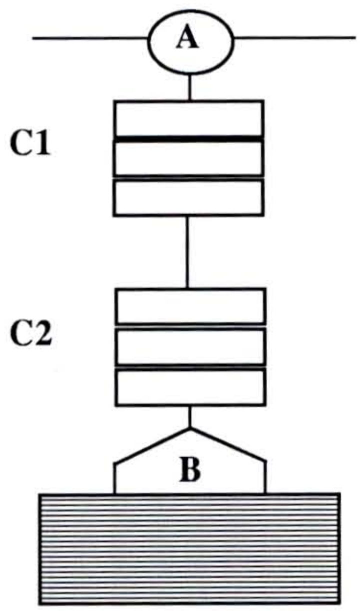

Figure 1 : Diagram of the experimental structure
(**A** : Buoy **B** : Anchor)
(**C1** : oyster baskets located near the surface)
(**C2** : oyster baskets near the bottom)

Pauly and Gaschütz (1979) modified (1) to account for seasonally oscillating growth :

$$\mathbf{Lf} = Linf\,[1 - \exp\,[- K\,(\mathbf{t} - t_o) + (CK/2\pi)\sin\,(\mathbf{t} - t_s)]]\ (2)$$

Appledoorn (1987) defined a new model so that tagging data could be used to estimate model parameters :

$$\mathbf{Lf} = Linf - (Linf - \mathbf{L_i})\,.\,\exp\,[- K\mathbf{d} + (CK/\pi)\sin\,(-\pi\mathbf{d})\cos\,(\pi\,(2\mathbf{t} + \mathbf{d} - 2M))]\ (3)$$

Only time interval between two samples was needed. Thus time needed no longer be expressed in an absolute sense, which was often unknown.

Variables are :

Li Length in millimeters at t.
Lf Length in millimeters at t+d.
d Time interval between 2 sampling dates.
t Day of initial measurement as a fraction of the year from 1st January.

Parameters are :

Linf Asymptotic length.
K Growth parameter.
C Magnitude of growth oscillation.
M Fraction of the year past 1 st January when maximum growth occurs.

The equation (3) can be modified in a linear form :

$$\mathrm{Ln}\,[(Linf - \mathbf{Lf})/(Linf - \mathbf{L_i})] = K\,[- \mathbf{d} + (C/\pi)\sin\,(- \pi\mathbf{d})\cos\,(\pi(2t + \mathbf{d} - 2M))]\quad (4)$$

Schnute (1982) provides a simplex method for parameter estimation of non linear equations.

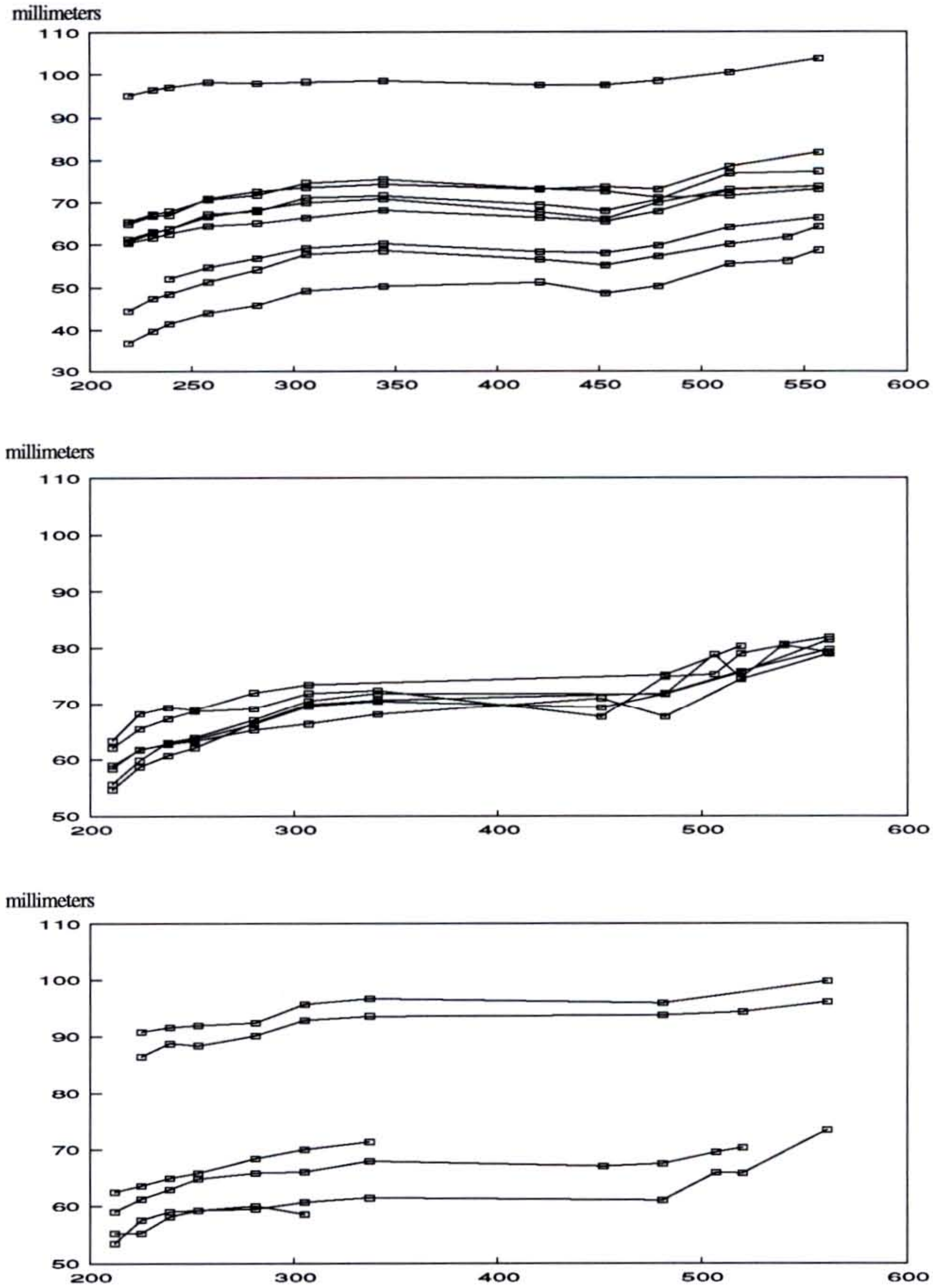

Figure 2 : Evolution of oyster growth at the three stations

A : CBL's Pier station

B : Green Holly Pound station

C : Benedict Bridge station

(X is expressed in days from 1989/01/01)

RESULTS

Appendix and figure 2 show observed growth at the three stations. Beaven (1950) related significant growth rate at CBL's pier station (20 mm from May'47 to May'48 for 60 mm oyster. In that study, growth is about 15 mm for the same period for 60 mm oyster (initial mean size).

The most rapid growth occured at Green Holly Pound for oysters of an 60 mm initial mean size. At the three stations, maximum growth occured from april to november when temperatures are above 10°C. Similar results were found by Abbe (1987) and Paynter Dimichele (1990). In winter, growth ceased and hard climatic conditions caused a decrease of mean length by breaking recently formed shell.

Growth model

The application of model (3) to the entire set of data (3 stations) provided an estimation of L_{inf} = 119.2 mm (N = 204 ; RSS = 560).

This estimation was consistent with measured lengths of animals from natural oysters bars.

With L_{inf} = 119.2 ,parameters K, C, M were estimated separately for each station and resumed in table 2. Green Holly Pond showed a higher value of K. C was constant over the 3 stations and M defined the maximum growth rate at the end of July'89 at Green Holly Pound and Benedict and at the beginning of August for CBL's Pier station.

A F–test was performed to compare growth curves :

with p = 9 and N = 204.

$$F = \frac{\left(RSS - \sum_{i=1}^{3} RSSi\right)/(p-3)}{\sum_{i=1}^{3} RSSi/(N-p)}$$

The residual sum of squares RSS was provided by the model without station effect and the RSSi's were the residual sums of squares for each station.

	PIER	GREEN	BENEDICT
Linf	119	119	119
K	0.33	0.51	0.36
C	1.52	1.33	1.56
M	0.59	0.53	0.52
Nb	99	59	46
RSS	201	243	62

Table 1 : Estimation of parameters (K, C, M) from model (3) for each station ; Nb : number of data ; RSS : Residual Sum and squares.

	PIER		GREEN	BENEDICT
	SPAT	SMALL	SMALL	SMALL
SURFACE	0.36	0.32	0.46	0.33
BOTTOM	0.30	0.27	0.54	0.36
F-test	0.48 (NS)	0.53 (NS)	0.47 (NS)	0.07 (NS)
DENSITY $220/m^2$	0.24		0.49	0.41
DENSITY $360/m^2$	0.31		0.44	0.22
DENSITY $660/m^2$	0.36		0.57	0.35
F-test	0.92 (NS)		0.43 (NS)	0.96 (NS)

Table 2 : Estimation of growth parameter K at the three stations CBL's Pier, Green Holly Pond, Benedict Bridge and F-test for each controlled factor (depth, density).

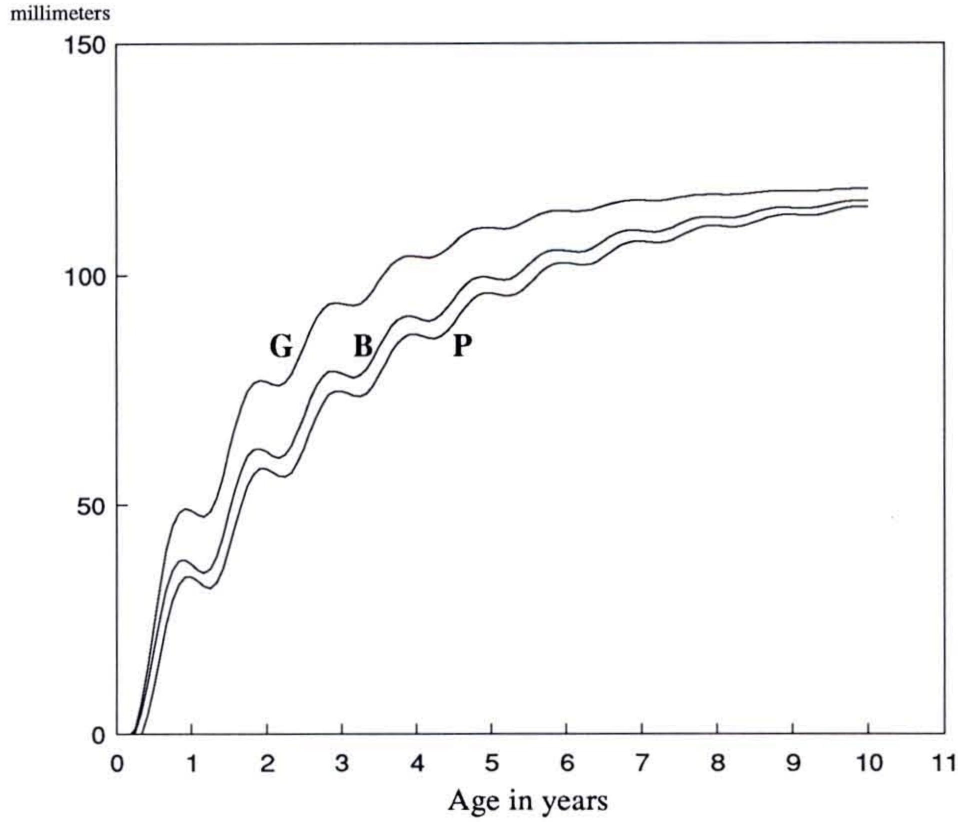

Figure 3 : Growth simulation at Green Holly Pound(**G**), Benedict Bridge(**B**) and CBL's Pier station(**P**)

The computed value 3.47 exceeded the five percent value of F (2.21) giving evidence of differences between the growth curves.

Figure 3 shows a 10-years growth simulation for the three stations. Green Holly Pound's oysters showed a higher growth rate according to measured values.

Fig 6, 7, 8, 9, 10 show the predicted and measured values for each controlled factor at the three stations.

Effect of depth and density

Effect of depth and density were tested separately. For each factor, C and M parameters were constant and equal to the computed values for the station. Model (4) was then applied. F tests showed no significative differences for the length of the shell between surface and bottom, neither between the densities.

DISCUSSION

Many authors reported models with seasonal trends (Hanumara, 1987 ; Lockwood, 1974 ; Askew, 1978). Some of them (Hall, 1984 ; Ursin, 1963) used direct effect of temperature. In that study, the incorporation of a sinus curve in the growth model allowed the estimation of M. That value could be compared with the modelling of temperature by a sinus curve, which showed a maximum temperature on the 1st August (fig. 4). Maximum growth predicted by the model was exactly in keeping with the highest temperature recorded during the year'89.

In Winter the stop of the growth rate occured when temperatures decreased belowe 10° celsius.

Natural oysters in Chesapeake Bay generally required three growing seasons to reach the marketable size of 76 mm (Beaven, 195O ; Abbe, 1987 ; Paynter Dimichele, 1990).

Paynter Dimichele (1990) reported growth rates of cultchless oysters in floating trays near Solomons Island in'87 and 88. Native oysters reached 40 mm in the first growing season and 78 mm after the second one. Abbe (1987) reported acceleration of growth rates due to suspending oysters in trays. In the present

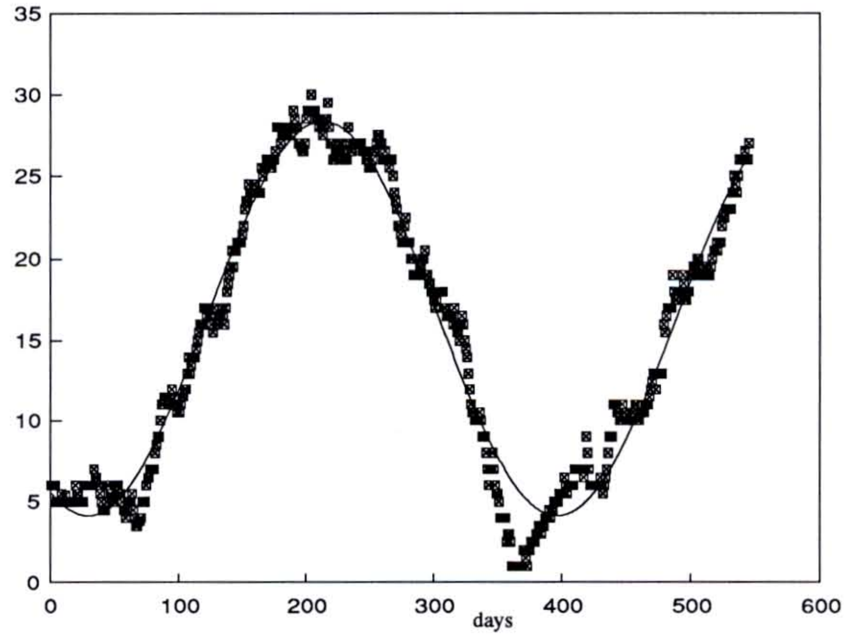

Figure 4 : Measured and predicted temperatures from 1st January 1989 expressed in °C

Predictive model $T°C = -12.1 \sin(2\pi t/365+1.068)+16.22$

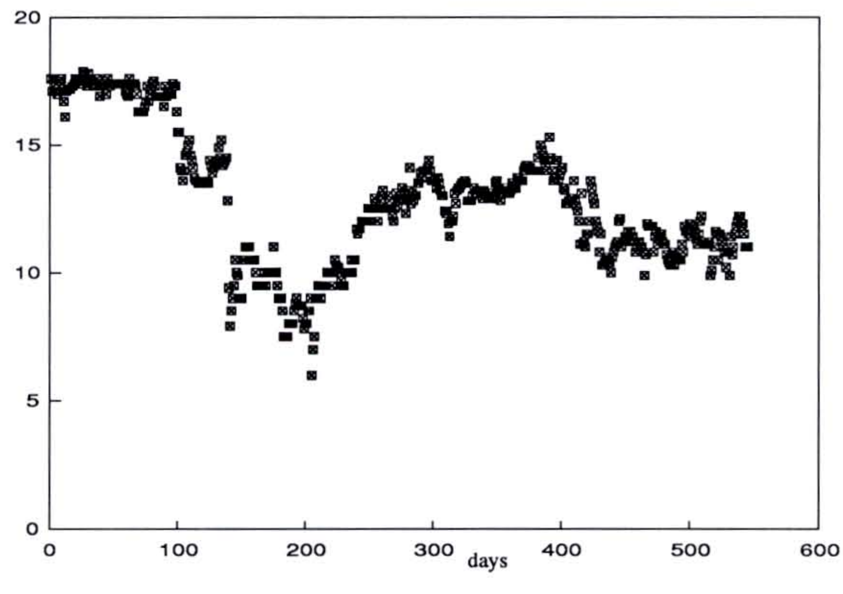

Figure 5 : Evolution of the salinity expressed in °/.. from 1st January 1989

(X is expressed in days from 1989/01/01)

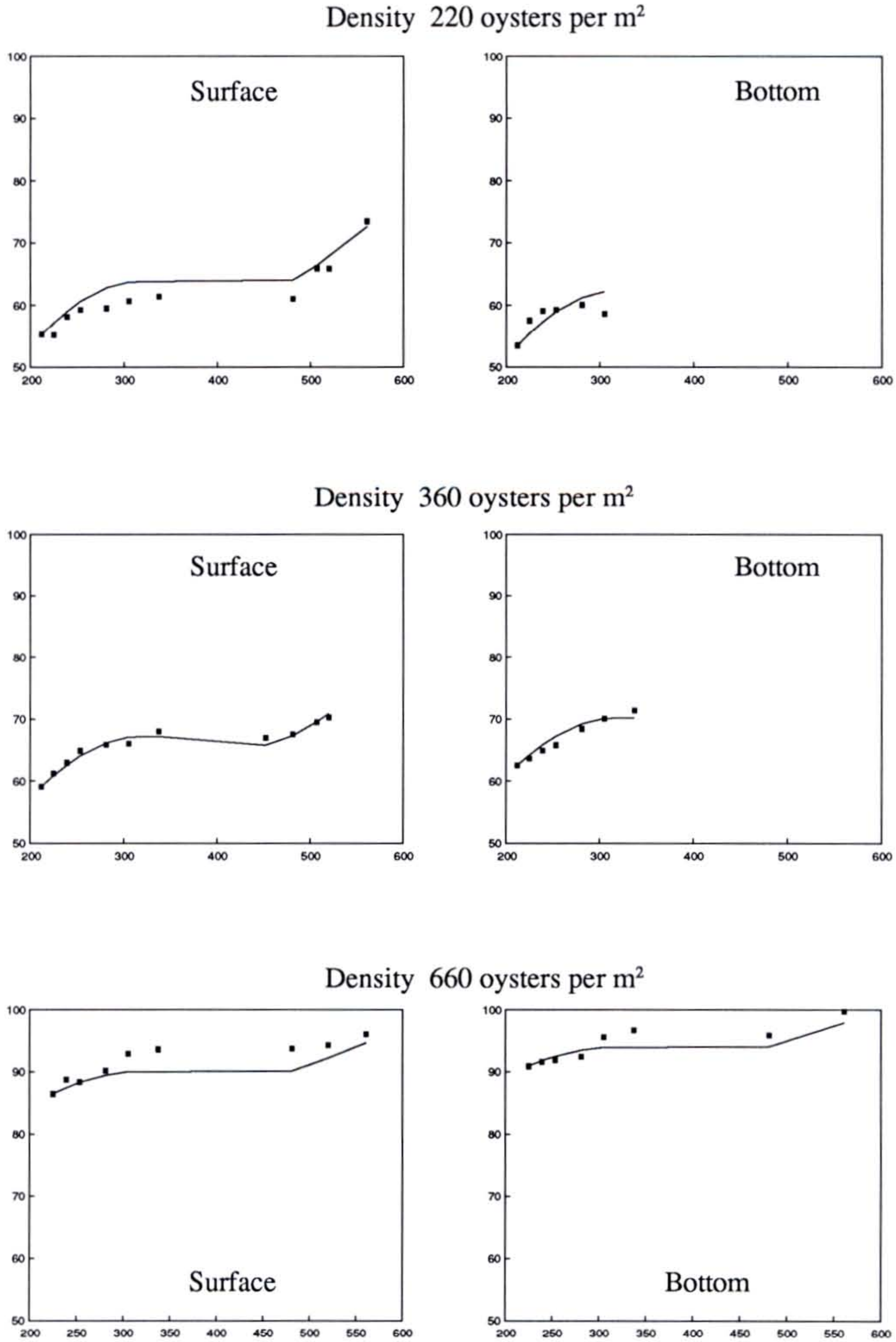

Figure 6 : Predicted and measured growth at Benedict Bridge station
(X is expressed in days from 1989/01/01)

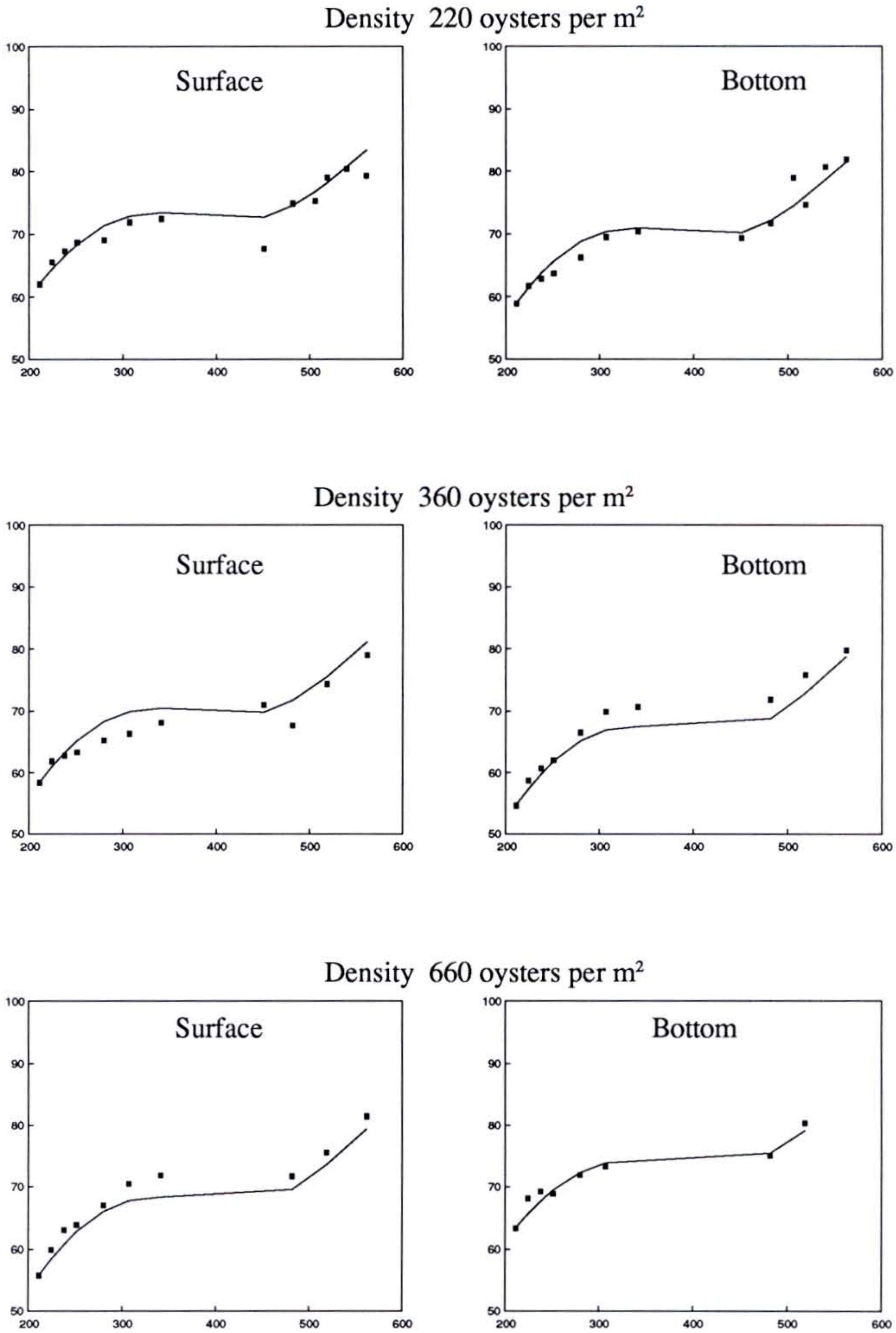

Figure 7 : Predicted and measured growth at Green Holly Pound station
(X is expressed in days from 1989/01/01)

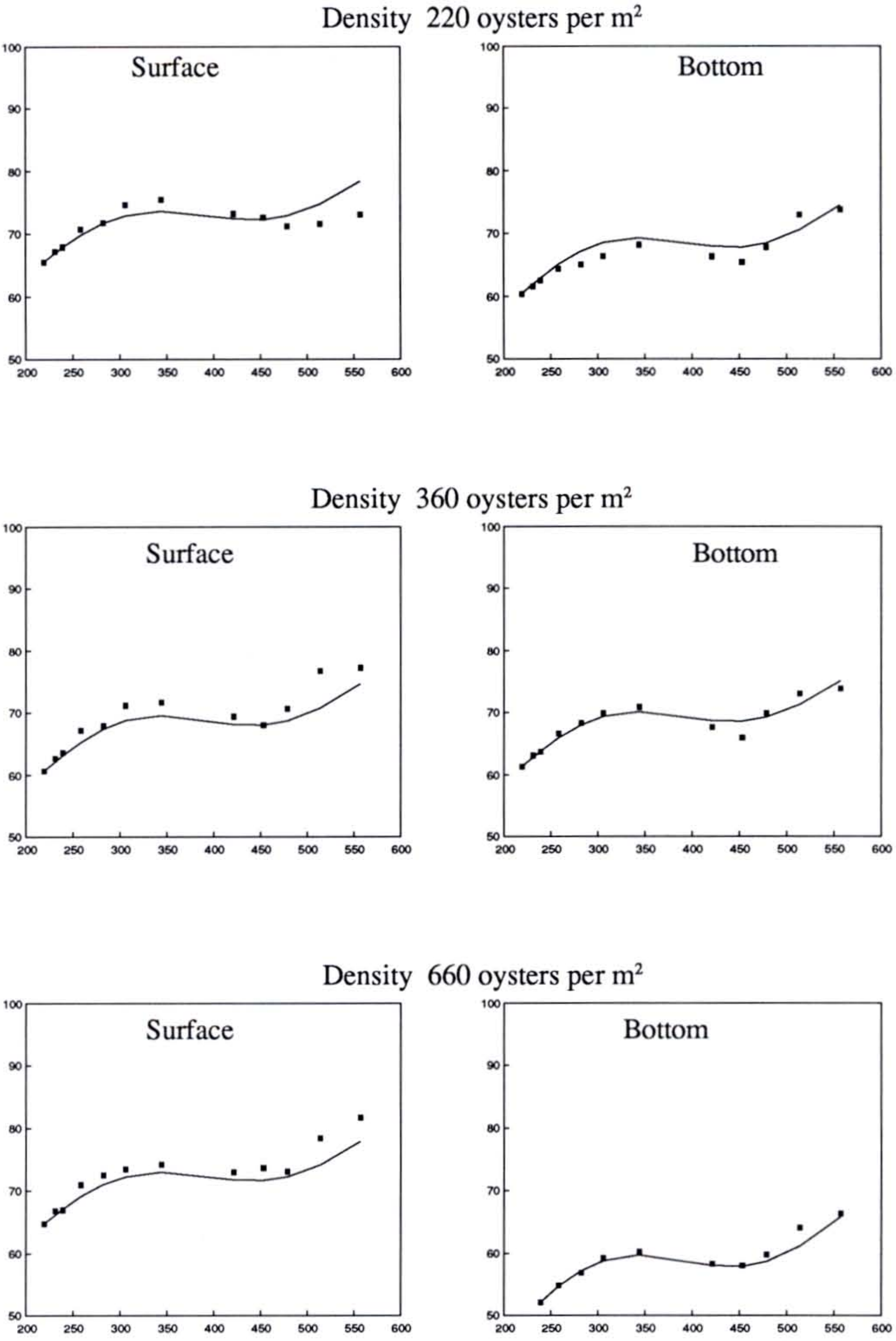

Figure 8 : Predicted and measured growth at CBL's Pier station
(X is expressed in days from 1989/01/01)

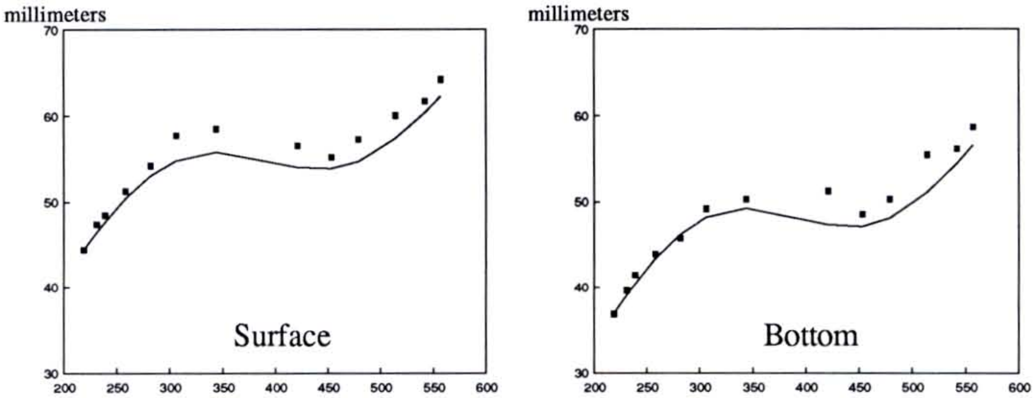

Figure 9 : Predicted and measured growth at CBL's Pier station (oyster spat)

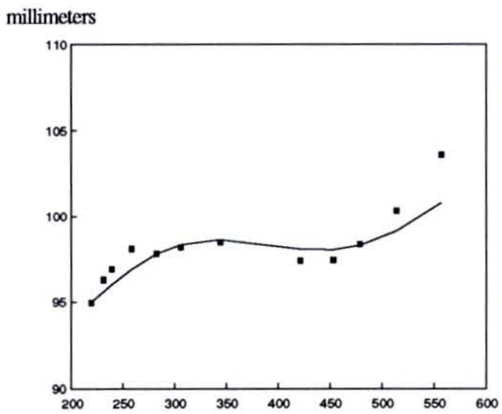

Figure 10 : Predicted and measured growth at CBL's Pier station (market size)
(X is expressed in days from 1989/01/01)

study, local conditions (Grenne Holly Pond) permited a marketable size of 76 mm after 2 growing seasons and 3 years for the two other stations.

As the salinity had been involved to cause slower growth rates in 1972 (Abbe, 1987) and as relative low salinity level had been noted for 1989 (fig. 5), a better growth rate could be expected on normal year particularly for the upper station of Benedict Bridge.

A future analysis of the growth rate together with the trophic parameters will demonstrate if it is only the temperature factor which accounts for the growth of the shell.

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APPENDIX

PIER (SMALL)

DENSITY	220/m2		360/m2		660/m2	
DEPTH	Surface	Bottom	Surface	Bottom	Surface	Bottom
DATE						
89/08/9	65.50	60.37	60.65	61.30	64.81	-
89/08/21	67.18	61.57	62.72	63.12	66.82	-
89/08/29	67.89	62.56	63.68	63.73	66.99	52.05
89/09/20	70.70	64.41	67.19	66.63	71.00	54.71
89/10/10	71.78	65.07	67.89	68.32	72.57	56.80
89/11/6	74.62	66.35	71.14	69.92	73.50	59.16
89/12/14	75.45	68.15	71.64	70.87	74.21	60.21
90/02/26	73.18	66.31	69.39	67.67	72.98	58.27
90/03/28	72.60	65.46	68.03	65.98	73.69	58.00
90/04/26	71.17	67.81	70.66	69.91	73.09	59.80
90/05/29	71.57	72.95	76.78	73.07	78.42	64.16
90/07/12	73.02	73.79	77.29	73.86	81.67	66.37

Oyster shell length in millimeter at CBL's Pier station (small size).

BENEDICT (SMALL)

DENSITY	220/m2		360/m2		660/m2	
DEPTH	Surface	Bottom	Surface	Bottom	Surface	Bottom
DATE						
89/08/2	55.27	53.46	59.05	62.53	-	-
89/08/15	55.20	57.55	61.26	63.64	86.47	90.86
89/08/27	58.13	59.07	62.97	64.93	88.74	91.58
89/09/11	59.25	59.25	64.89	65.83	88.39	91.90
89/10/10	59.51	60.07	65.88	68.45	90.16	92.40
89/11/6	60.70	58.64	66.07	70.05	92.86	95.59
89/12/14	61.44	-	68.01	71.34	93.56	96.65
90/03/28	-	-	67.04	-	-	-
90/04/26	61.06	-	67.54	-	93.74	95.88
90/05/22	65.94	-	69.53	-	-	-
90/06/5	65.89	-	70.30	-	94.28	-
90/07/16	73.47	66.72	-	-	96.03	99.74

Oyster shell length in millimeter at Bendict Bridge station (small size).

GREEN (SMALL)

DENSITY	220/m2		360/m2		660/m2	
DEPTH	Surface	Bottom	Surface	Bottom	Surface	Bottom
DATE						
89/08/2	62.03	58.93	58.39	54.67	55.70	63.30
89/08/15	65.52	61.72	61.83	58.71	59.84	68.19
89/08/27	67.28	62.79	62.73	60.67	63.06	69.26
89/09/11	68.66	63.63	63.25	62.01	63.89	68.88
89/10/10	69.08	66.22	65.24	66.49	67.03	72.02
89/11/6	71.89	69.49	66.32	69.87	70.46	73.42
89/12/14	72.46	70.39	68.09	70.67	71.89	-
90/02/26	67.63	69.31	71.03	-	-	-
90/03/28	74.86	71.71	67.63	71.89	71.76	75.15
90/04/26	75.32	78.89	-	-	-	-
90/06/5	79.01	74.62	74.40	75.87	75.63	80.37
90/06/25	80.43	80.71	-	-	-	-
90/07/16	79.30	81.91	79.01	79.78	81.45	-

Oyster shell length in millimeter at Green Holly Pond station (small size).

PIER (SPAT)

Depth	Surface	Bottom
89/08/9	44.46	36.81
89/08/21	47.43	39.65
89/08/29	48.46	41.45
89/09/20	51.26	43.94
89/10/10	54.19	45.80
89/11/6	57.73	49.18
89/12/14	58.51	50.27
90/02/26	56.52	51.20
90/03/28	55.17	48.57
90/04/26	57.27	50.29
90/05/29	60.09	55.46
90/06/27	61.75	56.15
90/07/12	64.26	58.68

Oyster shell length in millimeter at CBL's Pier station (spat size).

PIER (MARKET)

Date	
89/08/9	94.96
89/08/21	96.28
89/08/29	96.88
89/09/20	98.07
89/10/10	97.77
89/11/6	98.16
89/12/14	98.46
90/02/26	97.38
90/03/28	97.42
90/04/26	98.34
90/05/29	100.33
90/07/12	103.60

Oyster shell length in millimeter at CBL's Pier station (market size).