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Growth and Mortality Parameters for the Soft Clam (Mya arenaria L.) in a Danish Estuary, and an Estimate of Yield

by

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Introduction.

The soft clam (Mya arenaria L.) is a very common species in the Danish estuaries. From time to time, therefore, it has been discussed whether this clam could be commercially exploited, as it is in other countries. In relation to this it would be relevant to work out growth and mortality parameters for this clam, these subjects being the basic ones in modern fishery biology.

This paper deals with these parameters and the use of them in estimating the potential yield at a given locality. Most of the models used here are described in Beverton & Holt (1957).

Locality, Material and Methods.

The material on which the following results are based was collected during 1969 and 1970 in the inner part of Roskilde Fjord, a typically Danish estuary. The very shallow-watered locality was constantly water-covered.

All the samples were quantitative, and were obtained by digging with spade within an iron frame which covered 1/8 m^2. The density and mortality estimates are based on the 15 samples taken in 1969; these were also used for the empirical value of the biomass.

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The density of the clams on the locality appears from table 1. It also appears from the table that the distribution is aggregated.

Growth in length.

The growth equation to be used here is the von Bertalanffy growth equation

$$l_t = L_\infty (1 - e^{-K(t-t_o)}) \qquad (1)$$

whose parameters (L_∞, K and t_o) can be determined from the annual growth increments, which in this case are given in the winterrings (yearrings). For derivation of the growth equation, and estimating its parameters see Beverton & Holt (1957).

Some difficulties were encountered in determining these winterrings. The fact that only half of the individuals in the samples showed well-marked rings makes it a little doubtfull, if they are winterrings, but observations of the 1969 year-class confirm the winterring.-assumption. Table 2 shows the distribution of the winterrings used for estimating the growth equation.

The parameters of the growth equation were determined by plotting l_t against l_{t+1} (L_∞ and K) and by plotting $\ln(\frac{L_\infty - l_t}{L_\infty})$ against t (t_o); l_t is the mean value of the different winterrings. Both straight lines were estimated by regression analysis. The growth curve and the parameter values appears from fig. 1.

Growth in weight.

The length-weight relation was calculated for the body weight at different times during the year assuming an isometric growth pattern, $w = q \cdot l^3$ (w = wet weight of body, l=length of shell). The fact that some of the samples revealed a slightly allometric growth pattern is considered of no practical importance; the results are given in table 3.

The high q-value in May corresponds to the ripe gonads at this time, and it is clear that the best yield is to be had when harvesting the clams at this time.

When inserting $w = q \cdot l^3$ in (1) the von Bertalanffy growth equation in weight is obtained, but it must be remembered that in this no seasonal fluctuations in weight is reflected. Fig. 2 shows a weight-age curve using a q-value, which is the arithmetic mean of the different q-values.

Mortality.

The estimate of natural mortality is based on the assumption:

$$\frac{dN}{dt} = -M \cdot N_t \qquad (2)$$

where M is the natural mortality coefficient. Assuming that the recruitment is constant every year the M-value can be obtained from the age-composition in the population. But it must be emphasized that although the model (2) is widely used and easily incorporated in yield and biomass equations it is very unlikely that the mortality is independent of age, size or growth rate. The results of Theisen (1968) for Mytilus edulis probably also holds for Mya.

Here I have calculated M from the age-composition. The individuals, which could not be age-determined by winterrings, were "given" an age based on the calculated growth curve, see table 4. The regression line determined by the plot of $\ln N_t$ against age (t) gives a M-value of about o.6, but the large variance $s_M^2 = 0.02368$, makes the estimate a little uncertain.

Spear & Glude (1957) provide data, which can be used for an estimate of M for Mya. Transplanted and marked individuals were followed throughout 1 year by monthly sampling, see table A1, A2 in Spear & Glude (1957). The M-value resulting from these data is in good accordance with my own, but again, most unfortunately, the variance of these estimates is also very large.

In the following calculations I have used the M-value of 0.6.

When knowing M a theoretical age-composition of the population can be calculated from the expression:

$$\bar{N} = \frac{1}{T} \int_0^1 N_t \cdot e^{-Mt} dt$$

Putting T = 1 the mean number of individuals of a year-class during one year is obtained, see table 5.

Estimating yield.

Beverton & Holt (1957) have shown how the von Bertalanffy growth parameters and a constant M is incorporated in an expression for biomass (standing crop), assuming a steady-state equilibrium in the population. The biomass can be expressed as

$$B = \int_{t_o}^{t_{max}} N_t \cdot w_t dt$$

where $N_t = N_o \cdot e^{-Mt}$, and $w_t = W_\infty (1 - e^{-K(t-t_o)})^3$; putting $t_o = 0$ and $t_{max} = \infty$, a simplified expression is obtained:

$$B = N_o \cdot W_\infty \left(\frac{1}{M} - \frac{3}{M+K} + \frac{3}{M+2K} - \frac{1}{M+3K}\right)$$

Inserting the values of N_o, W_∞, M and K, the biomass (body weight per m^2) of all year-classes is obtained.

The question then arises, how realistic the calculated value of B is. Table 6 shows the values of the weighing of the 15 samples mentioned above. There is great variation among the individual values, which was to be expected from the aggregated distribution, but to my opinion there is a reasonable good agreement between the calculated value and the mean of the empirical values.

When operating with a market-size of about 50 mm for Mya, it is seen from table 4 & 5, that the density of market-size individuals is about 10 per m^2, and this density should be great enough for a commercial fishery using a hydraulic clam dredge. Assuming that the clam dredge removes all market-size individuals on its way through the bottom, the yield should be calculated simply as the biomass of these individuals (the biomass of clams which 6 years or older.

This I have calculated as:

$$Y = \int_0^\infty N_t \cdot w_t dt - \int_0^5 N_t \cdot w_t dt = B - 92.72 =$$

about 50 g per m^2 or 500 kg per ha.

Following this model it needs to be stressed that if any area is exploited one year it should not be exploited the following 3-4 years to allow the younger year-classes to attain market-size. Therefore a possible fishery based on these densities requires large areas, so that different areas are exploited in differens years.

References:

Beverton & Holt, 1957: On the dynamics of exploited fish populations. Fish. Invest., ser. 2 (19).

Spear & Glude, 1957: Effects of environment and heredity on growth of the soft clam (*Mya arenaria*). U.S. Fish and Wildlife Serv. Fish. Bull. 114, 57, p. 279-92.

Theisen, B., 1968: Growth and Mortality of Culture Mussels in the Danish Wadden Sea. Medd. Danm. Fisk.Havunders. N.S. 6 (3).

Table 1. Distribution and density of the clams from 15 samples taken in 1969. (0.125 m^2)

sample no.	older year-classes	year-class 1969	total
1	32	39	71
2	27	153	180
3	22	77	99
4	6	22	28
5	0	0	0
6	15	53	68
7	16	62	78
8	14	35	49
9	9	90	99
10	10	87	97
11	6	10	16
12	3	13	16
13	5	8	13
14	3	11	14
15	12	123	135
mean/ sample:	12	52.2	64.2
mean / m^2:	96	417.6	513.6

Table 2.

Length distribution of the measured winterrings.

mm	1.ring	2.ring	3.ring	4.ring	5.ring	6.ring
60						
59						
58						
57					1	
56						1
55						
54						
53						
52					1	
51						
50				1		1
49				1		
48				1	1	
47						
46				1	1	1
45						
44			2		1	
43				1		
42			1			
41			2	3	2	
40			3	2		
39			3	1		
38			4	1		
37		2		1		
36		1	4	3		
35		3	2	1		
34		1	4			
33		5	6	1		
32		4	2			
31		4	2			
30		13	3			
29		9		1		
28		14	2			
27		8	1			
26		12				
25		11				
24	3	7	2			
23	2	6				
22	5	7				
21	6	5				
20	8	2				
19	12					
18	19	1				
17	15					
16	18	1				
15	22					
14	14					
13	14					
12	12					
11	10					
10	5					
9	3					
8	1					
7						
	169	116	43	19	7	3

Table 3.

q-values for Mya arenaria at different times during the year.

(Body weight)

Date	q
28-5-1969	$3.8 \cdot 10^{-5}$
14-7-1969	$3.0 \cdot 10^{-5}$
4-8-1969	$3.0 \cdot 10^{-5}$
8-9-1969	$3.0 \cdot 10^{-5}$
21-10-1969	$3.2 \cdot 10^{-5}$
24-3-1970	$2.0 \cdot 10^{-5}$
15-5-1970	$4.7 \cdot 10^{-5}$

Table 4.

Age-composition during 1969.

Age	Individuals age-determined from the estimated growth curve	Individuals age-determined by means of winterrings	Total age-composition
0	0 (0-15.3 mm)	783	783
1	6 (15.4-26.3 mm)	27	33
2	25 (26.4-34.6 mm)	32	57
3	29 (34.7-41.3 mm)	12	41
4	15 (41.4-46.5 mm)	7	22
5	9 (46.6-50.7 mm)	3	12
6	2 (50.8-54.0 mm)	3	5
>6	(3) (>54.1 mm)	(0)	(3)

Table 5.

The calculated age-composition in the population (M = 0.6)

N_t	$N_o \cdot e^{-Mt}$	$\bar{N} = \int_0^1 N_t \cdot e^{-Mt} dt$
N_o	133.42	
		100.34
N_1	73.21	
		55.06
N_2	40.18	
		33.22
N_3	22.05	
		16.58
N_4	12.10	
		9.10
N_5	6.64	
		5.00
N_6	3.65	
		2.75
N_7	2.25	
		1.69
N_8	1.10	
		0.82
N_9	0.60	
		0.45
N_{10}	0.33	

Table 6. The body weight of the clams from the 15 samples. Grams / m^2.

sample no.	older year-classes	year-class 1969	total
1	343.52	1.71	345.23
2	454.08	10.33	464.41
3	278.72	32.24	304.96
4	76.88	9.18	86.06
5	0	0	0
6	220.96	24.48	245.44
7	194.72	33.18	227.90
8	109.60	17.54	127.44
9	95.68	81.64	177.33
10	178.56	112.48	291.04
11	67.52	9.52	77.04
12	36.56	11.60	48.56
13	34.56	3.20	37.76
14	18.32	6.08	24.40
15	274.16	192.16	466.32

Total mean weight: 194.8 g

Fig. 1

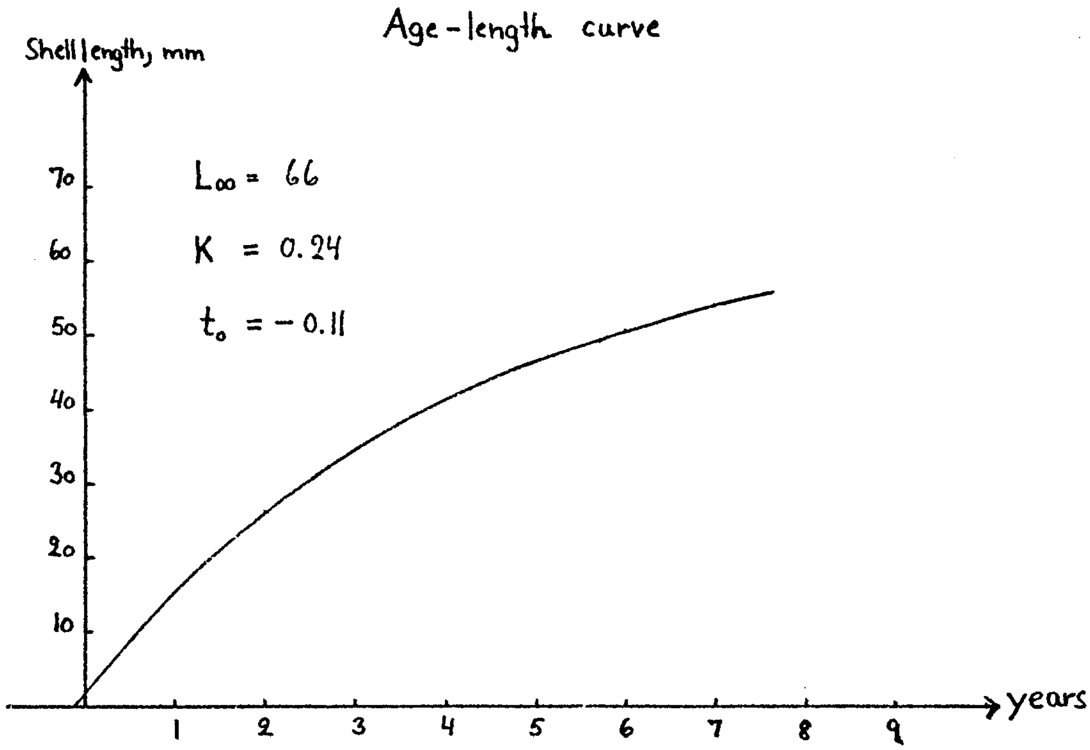
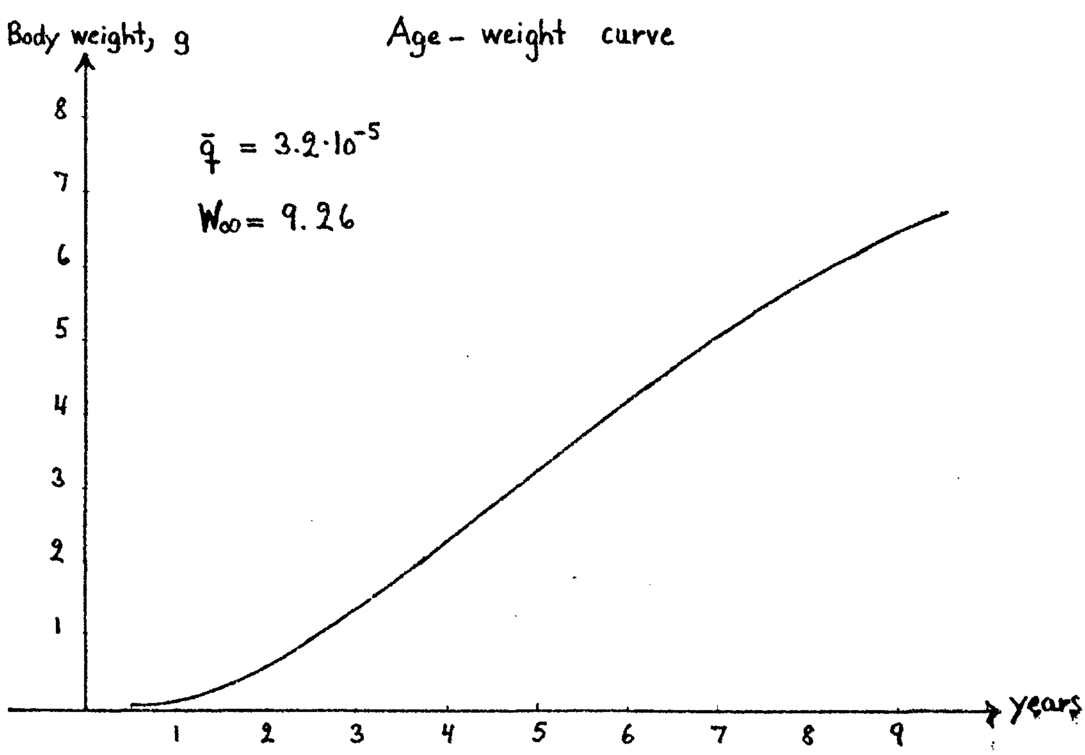

Age-length curve
Shell length, mm
70
60
50
40
30
20
10
L∞ = 66
K = 0.24
t₀ = -0.11
1
2
3
4
5
6
7
8
9
years

Fig. 2


Age-weight curve
Body weight, g
8
7
6
5
4
3
2
1
q̄ = 3.2·10⁻⁵
W∞ = 9.26
1
2
3
4
5
6
7
8
9
years