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Growth and population structure of a northern shallow-water population of the Giant Scallop, *Placopecten magellanicus* (Gmelin)

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Introduction

The Giant Scallop, *Placopecten magellanicus* (Gmelin) ranges from Pistolet Bay, Newfoundland (Squires 1962) to Cape Hatteras, North Carolina, in depths to 110 m (Posgay 1957); they occur in shallower water in the northern portion of their range.

While age and growth of the species have been studied elsewhere (e.g. Stevenson and Dickie 1954, Dickie 1955, Merrill *et al*. 1966), little is known regarding population structure, morphometrics and rate of growth of the shallow-water populations near the northern limit of the range. The present study was undertaken to determine growth variations among three beds in Port au Port Bay (Lat 48°40'N) and data from these populations were also used for comparison with those from more southerly areas. The populations studied are close to the northern limit of the range and exhibit growth features which appear to reflect the wide annual fluctuations in temperature characteristic of the shallow-water environment.

Scallop landings from Port au Port Bay increased, with minor fluctuations, from the beginnings of the fishery in the late 1930's to a peak of 188,600 Kg (adductor muscles) in 1955 (Squires 1962). Since then a spectacular decline in landings occurred and it appears that overfishing was the major factor contributing to this decline (Naidu MS 1969).

Materials and Methods

Scallops were collected from three beds within Port au Port Bay (Fig. 1); these were: West Bay (11-13 m), Boswarlos (7-15 m), and Fox Island River (11-16 m). Collections were made with a simple, covered hand dredge equipped with 6.5 cm (internal diameter) rings from the Boswarlos bed at weekly intervals in 1966 and at monthly intervals in 1967. The 1968 Boswarlos sample and the West Bay and Fox Island River samples collected in 1966 represent unculled commercial catches by local fishermen. In addition, several small samples were taken during late winter to determine the time of formation of annual rings. All observations were made on live, freshly-caught scallops.

Age determinations were usually made from the annual rings on the surface of left valves. Rings were particularly prominent on the shell surface. With the exception of *Lithothamnia* sp., which was often found in the umbonal region, epifaunal organisms on the shell surface such as *Anomia* sp. and *Crepidula fornicata* are easily removed to expose the growth rings. When the rings were obliterated by heavy surface growth of saxicolous crustose corallines, as was often the case in scallops from the Boswarlos bed, the calcareous parts of the resilia were used (Merrill *et al*. 1966). As the growth lines on the resilia were often crowded, especially towards the ventral edge, it was found useful to immerse detached ligaments in tap water for several hours in order to cause the inter-annular spaces to expand and the growth rings to show more clearly.

Ageing was validated by tagging and releasing 250 scallops (ages 2+ to 7+) from the Boswarlos bed in 1966. Only specimens free of epibionts were used for tagging. A hole was drilled just over the byssal notch with Rotadent precision dental burrs.[1] A small numbered plastic disc was then attached by means of a nickel wire (Posgay 1963). Each of the 9 scallops subsequently recovered in 1967 had added one ring; four specimens recaptured in 1970 had two additional rings each.

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[1]Dentalborrfabriken A-B, Malmö, Sweden.

Examination of about 300 small scallops (under 60 mm) indicate that the first discernible ring is generally laid down during the second winter. Several small specimens under 20 mm in shell height obtained during the summer of 1966 did not possess recognizable growth rings. If September 1st is arbitrarily considered as the birth date of the Giant Scallop in Port au Port Bay (Naidu 1970) then the first permanent ring is not laid down until the end of the second winter. A scallop caught in July, showing only widely spaced concentric circuli, was considered to be in its first year of life and its age was designated as 0+. Supernumerary or even faint annual rings occasionally appear on 0+ scallops but these are not retained as the scallops get older.

Growth was estimated from measurement of distances between the umbo and the annuli on the left valve, the dorso-ventral distances being measured along the curvature of the valve using thin paper strips. The positions of the growth annuli on each left valve were marked off on a strip of paper stretched tightly over the contour of the valve. The strips were then laid over a rule calibrated in millimeters and the distances to the annuli read directly.

To compare this method with the standard one of measuring the tangential dorso-ventral distances, a sample of 416 scallops was also measured to yield tangential dorso-ventral heights at age. The efficiency of the two methods was examined critically and compared by methods-time measurement (Maynard et al. 1948, Karger and Bayha 1955).

Von Bertalanffy (1938) growth curves, of the type $L_t = L_\infty(1-e^{-K(t-t_o)})$, were fitted to four shell dimensions with age; shells with distorted valves were not used in growth studies. The method of fitting growth curves described by Allen (1966a) was used for all Port au Port Bay data, on the basis of weighted averages at various ages and iterative least squares. The method of Lal (cited by Naidu MS 1966) was used to obtain comparable figures for the Digby, Bay of Fundy, and George's Bank areas, on the basis of published arithmetic means at various ages and iterative least squares.

Results

Population structure

Scallops ranging in age from 0+ to 16+ were found in Port au Port Bay (Fig. 2). Recruitment on the Boswarlos bed was highly irregular, the 1955, 1956, 1960 and 1962 year-classes being particularly well represented. The paucity of scallops of the 1958 and 1961 year-classes was striking, as was the relative abundance of the 1963 year-class. Scallops on the West Bay and Fox Island River beds were generally older than those on the Boswarlos bed. Eight and nine-year-olds were most abundant (30 per cent) on the West Bay bed. About 35 per cent of scallops from the Fox Island River bed were nine to ten years old. The oldest scallop encountered (16+) came from the Fox Island River bed.

Shell-height distribution

The shell-height frequencies of scallops sampled from the Boswarlos bed in 1966 and 1967 were plotted separately (Fig. 3).

The cumulative time measurement units (Anon. 1955) for determining the shell height at age for the curvature and tangential methods for a three-year-old shell were 674.4 and 1249.2 giving corresponding times of 24.3 and 45.0 seconds, respectively (1 TMU = 0.036 seconds). Stop-watch checks of both methods verified the accuracy of the TMU estimates, clearly pointing to significant time savings through measurement of curvature distances.

The relations between the dorso-ventral height measured tangentially to the shell (DV) and the distance from the umbo to the shell margin of the left valve measured along the shell curvature (DC) for the three scallop beds are described as follows:

Boswarlos, $DC = 1.17DV-5.56$;
West Bay, $DC = 1.19DV-7.11$;
Fox Island River, $DC = 1.14DV-3.15$.

These equations may be used for converting tangential measurements to those along the curvature.

Age and growth

Irrespective of the method employed in fitting the von Bertalanffy growth equations, the rates of approach to asymptotic shell dimension (K) were constant but the unweighted fit gave consistently higher L_∞ values (Table 1). Scallops from the West Bay bed attained greater dimensions in all three shell dimensions selected for study, while those from the Fox Island River bed were consistently smaller (Table 2). Regardless of the asymptotic size attained by the population (L_∞) with respect to any of these shell dimensions, the K values for any one dimension within any one bed did not show much variation. An examination of the von Bertalanffy growth parameters of shell height at age and their 95 per cent confidence limits indicates complete overlap of L_∞ values for the Boswarlos and West Bay scallops and of K values for all areas. The L_∞ values for the Fox Island River bed do not, however, fall in the range observed for the Boswarlos and West Bay beds.

Fox Island River scallops not only grow more slowly than those from the Boswarlos and West Bay beds but have characteristically brittle and lighter shells (Table 3).

Comparison with published data indicates considerable geographical variation in shell growth (Table 4). Scallops from the more northerly latitudes appear to attain larger sizes than do those from the south. K values, on the other hand, decrease with increasing latitude.

Adductor muscle weights

The relationship between weight of the posterior adductor muscle and age of scallop was not linear, but application of a log transformation of ages produced an approximately linear relationship. At comparable ages beyond about six years West Bay scallops have the highest meat yield and those from the Boswarlos bed the lowest for the three beds (Table 5). An analysis of covariance indicates a highly significant ($P < 0.01$) difference between the slopes in the regressions of adductor muscle weight on age for the two beds. The largest increase in muscle weights occurs between the ages of V and VI on the Boswarlos and West Bay beds and between the ages of VI and VII on the Fox Island River bed. Beyond their sixth year scallops from the Boswarlos bed have the lowest meat yield. This roughly corresponds to the point of intersection of the least squares regressions of adductor muscle weight on log age.

Discussion

Unlike scallops from more southerly populations growth rings were particularly prominent on the left valves and little difficulty was encountered in assigning ages to animals in the present study. Supernumerary rings found in Port au Port Bay scallops may be ascribed largely to severe storms rather than to fishing activity which was minimal for several years prior to this investigation. There was some evidence of a general constriction in the spacing of the concentric circuli in mid-summer and early fall. This may be related to high summer temperatures and/or the onset of major spawning in early fall (Naidu 1970). These closely-spaced circuli are easily distinguished from the prominent annual rings.

The variations in year-class strength are similar to those found in or implied for Giant Scallop populations from other areas (e.g. Dickie 1955). The relative scarcity of small scallops in the biological samples from the Boswarlos bed in 1966-67 may be associated with the swimming behaviour of young scallops. Caddy (1968) has shown that swimming behaviour rather than dredge selection is responsible for the low dredge efficiency for the capture of scallops smaller than 100 mm; the small scallops can avoid approaching objects by swimming away from them. Both age (Fig. 2) and shell height (Fig. 3) compositions suggest a recovery of stocks subsequent to the cessation of intensive fishing after 1955.

The curvature method of measuring shell height is almost twice as rapid and less laborious than the conventional method. In the latter method, the investigator has to repeat the measuring procedure as many times as there are annual rings on the shell (e.g. with a pair of vernier calipers). In measuring curvature distances, however, all measurements are completed in a single operation. Presumably it also provides a more realistic estimate of shell growth than the tangential method for it measures the total column of shell secreted by the mantle, thereby bypassing the inherent variations in shell curvature. It also ensures that all measurements are taken along a straight line. The use of a graduated flexible tape would constitute a further improvement in the method.

The K values for the three beds (Table 1) support the argument of Beverton and Holt (1957) that K, which, on theoretical grounds, is independent of food consumption, remains relatively constant, and that changes in growth rate may be reflected by variations in L_∞ or W_∞ (asymptotic weight). Beverton and Holt (1959) point out that food and temperature account for most of the between-area variation encountered in a given species. They argue that food supply modifies the asymptotic length while temperature affects both K and L_∞ and that with increase in temperature K increases while L_∞ decreases.

We are here dealing with a confined shallow-water environment where hydrographic features are presumed to be similar on the three beds. Continuous, wind-induced circulation (Templeman 1939) during the reproductive phase of the scallop (Naidu 1970) would suggest that recruitment of young into any one bed may be reinforced by spat from adjoining beds; thus the variations are not likely related to genetic differences.

Lilly (MS 1965) has made direct underwater observations on sediments forming the upper layers of the scallop beds in the bay. He found muddy, organic compacted silt with pebbles (< 25 mm) on the Boswarlos bed, mixed silt, sand and gravel on the West Bay bed, and loosely-suspended organic silt and mud about 30 cm thick on the Fox Island River bed.

Both morphological and growth rate differences between scallops from the different beds suggest the operation of factors peculiar to the beds themselves. It is suggested here that the observed differences are related to variations in the silt-clay content among the beds. This suggestion is supported by the diet and feeding habits of the species which ingests benthic and tycopelagic diatoms. Davis and Marshall (1961) have indicated that much of the food of the Bay Scallop (Aequipecten irradians) is of benthic origin. Intermittent interruption in feeding together with the additional energy expended in removing fine sediments may inhibit growth of Giant Scallops. Loosanoff and Tommers (1948) and Hsiao (1950) have demonstrated impairment of feeding by silt in oysters through a decrease in the rate of feeding.

A further observation relating to this negative correlation between growth rate and silt-content is seen in the distribution of shell weights (Table 3). The large differences in shell weights observed in the Fox Island River scallops suggest that some other factor associated with the micro-environment appears to be interfering with the ability of the animal to deposit shell material.

The low yields in muscle weights (Table 5) in commercial-sized animals from the shallower Boswarlos bed are ascribed to an infection of these animals by a green, unicellular endozoic alga (Naidu and South 1970), recently described as the new species Coccomyxa parasitica by Stevenson and South (1974). It has been shown that the infection which adversely affects the soft parts sets in when the animal is between 4 and 6 years old and that the alga is largely restricted to areas of light accessibility (Naidu 1971). About 43 per cent of animals 8 years and over from the Boswarlos bed were infected while only 3 per cent of those from West Bay harboured the alga, and those from the Fox Island River bed were free from the infection (Naidu 1971).

The variations in growth rates of scallops from widely separated areas (Table 4) are more pronounced than those observed within Port au Port Bay. Scallops from the more northern areas have larger L_∞ values but K values are smaller. There is also a relationship between longevity (as measured by the maximum age recorded) and L_∞. The relatively slower growth rate in Port au Port Bay scallops is probably attributable to a shorter growing season where prolonged low winter temperature as well as debility through sudden temperature increases (Dickie and Medcof 1963) in cold adapted animals during the summer may be limiting to growth.

Summary

An alternative method of measuring scallop shells is presented. Methods-time measurement studies showed it to be nearly twice as rapid as the conventional method of measuring tangential shell heights.

Growth rate differences between scallops from three beds within Port au Port Bay, Newfoundland, are attributed to differences in the composition of the sediments on these beds. Scallops on the bed with the finest sediments grew more slowly than those on the beds with coarser sediments. Scallops near the northern limit of their range were found to grow more slowly but attain greater sizes and live longer than those farther south.

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Table 1. Von Bertalanffy growth parameters for *P. magellanicus* on the three beds in Port au Port Bay, (A) Allen's fit, (B) Lal's unweighted fit.

Bed	Parameter			Years fitted
	L_∞ (mm)	K	t_0	
Boswarlos	A. 172 ± 2.0[a]	0.22 ± 0.01	0.37 ± 0.08	1-15
	B. 179	0.20	0.30	
West Bay	A. 182 ± 11.0	0.21 ± 0.05	0.09 ± 0.63	2-15
	B. 185	0.21	0.34	
Fox Is. River	A. 152 ± 5.0	0.29 ± 0.06	0.55 ± 0.67	1-16
	B. 159	0.22	0.19	

[a] one standard deviation of the mean.

Table 2. Von Bertalanffy growth parameters for the (A) tangential dorso-ventral axis, (B) anterior-posterior axis and (C) wing-base of the left valve of scallops from the three beds.

Shell character	Parameter L_∞	K	t_0	Years fitted
(A) Dorso-ventral axis (mm)				
1. Boswarlos	152	0.21	-0.48	1-15
2. West Bay	161	0.19	-0.88	1-14
3. Fox Is. River	140	0.27	0.11	1-15
(B) Anterior-posterior axis (mm)				
1. Boswarlos	169	0.18	-0.64	1-15
2. West Bay	175	0.19	-0.50	1-14
3. Fox Is. River	150	0.25	0.22	1-15
(C) Wing-base (mm)				
1. Boswarlos	94.6	0.17	-0.49	1-15
2. West Bay	97.2	0.21	0.19	1-14
3. Fox Is. River	70.4	0.31	0.22	1-15

Table 3. Average dry shell weights (g) at various ages of scallops from the three beds.

Age (yr)	West Bay	Boswarlos	Fox Is. River
I+	-	11.0	-
II+	29.0	23.8	-
III+	39.0	43.9	33.0
IV+	78.9	72.6	70.7
V+	108.8	116.7	95.5
VI+	146.0	139.2	104.5
VII+	182.8	137.5	130.0
VIII+	199.0	186.4	138.1
IX+	227.0	192.9	139.1
X+	259.3	210.2	128.1

Table 4. Values for von Bertalanffy growth parameters of the Giant Scallop from several areas in the northwest Atlantic, (Lal's unweighted fit).

Area	Latitude North	Parameter L_∞ (mm)	K	t_0	Years fitted
Georges Bank (Merrill *et al.* 1966, Reader No. 1, p. 310)	41°52'	141	0.34	0.56	1-9
Grand Manan, Bay of Fundy (Stevenson, MS 1932, p. 17)	44°42'	151	0.36	0.68	1-9
Digby, Bay of Fundy, N.S. (Stevenson, MS 1932, p. 17)	44°42'	149	0.28	0.45	1-9
Boswarlos, Port au Port Bay, Nfld. (this paper)	48°40'	179	0.20	0.30	1-15

Table 5. Mean numbers per pound at various ages for scallops from the three beds and, in parentheses, mean weights (g) of adductor muscle.

Age (yr)	Boswarlos	West Bay	Fox Is. River
I+	363(1.3)	-	-
II+	128(3.6)	63(7.2)	-
III+	61(7.4)	43(10.6)	65(7.0)
IV+	34(13.2)	31(14.9)	35(12.8)
V+	25(18.3)	22(20.7)	26(17.4)
VI+	19(24.1)	16(29.0)	20(22.2)
VII+	17(27.5)	14(33.3)	16(28.6)
VIII+	18(25.1)	13(34.4)	14(31.7)
IX+	16(28.6)	13(36.2)	13(34.7)
X+	14(31.6)	12(39.0)	13(33.6)
XI+	13(34.0)	13(33.9)	-
XII+	12(37.5)	11(40.0)	13(34.1)
XIII+	11(39.8)	10(43.8)	-
XIV+	12(33.6)	-	12(36.6)
XV+	14(31.8)	10(47.00)	-

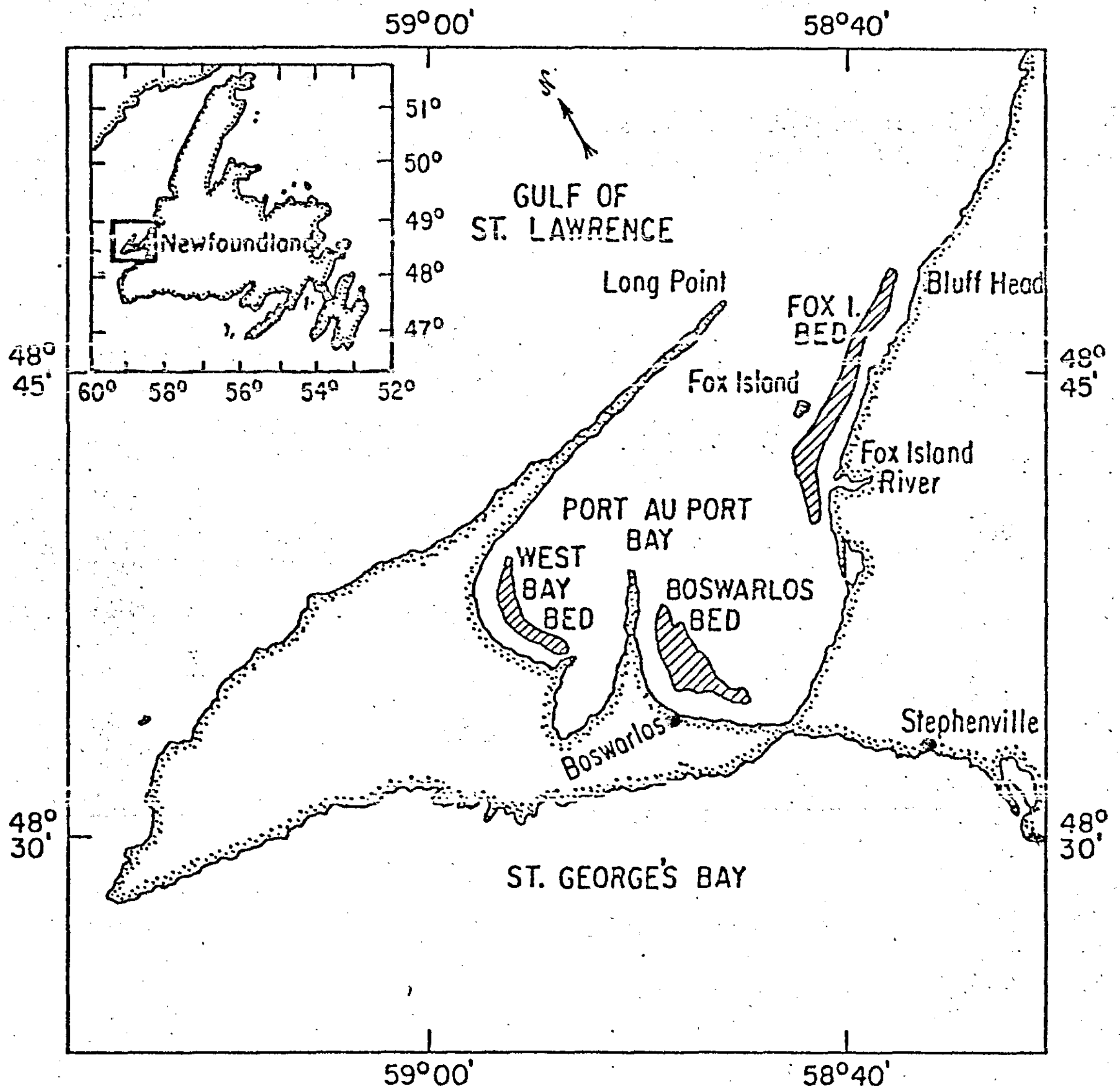

Fig. 1. Locations of the three scallop beds in Port au Port Bay, Southwestern Newfoundland.

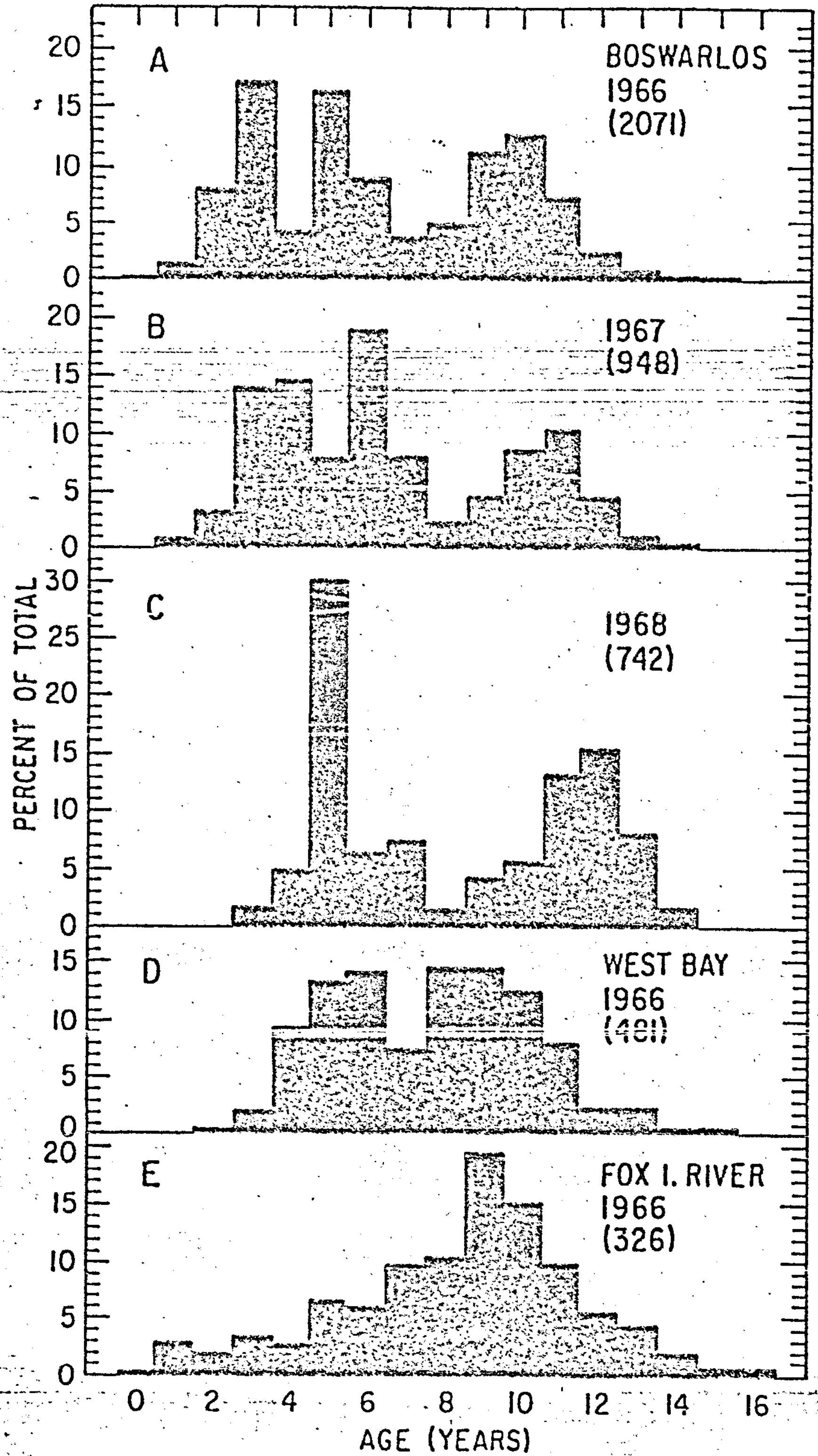

Fig. 2. Age-composition of scallops from the three beds during 1966-68. Numerals after the years indicate sample sizes.

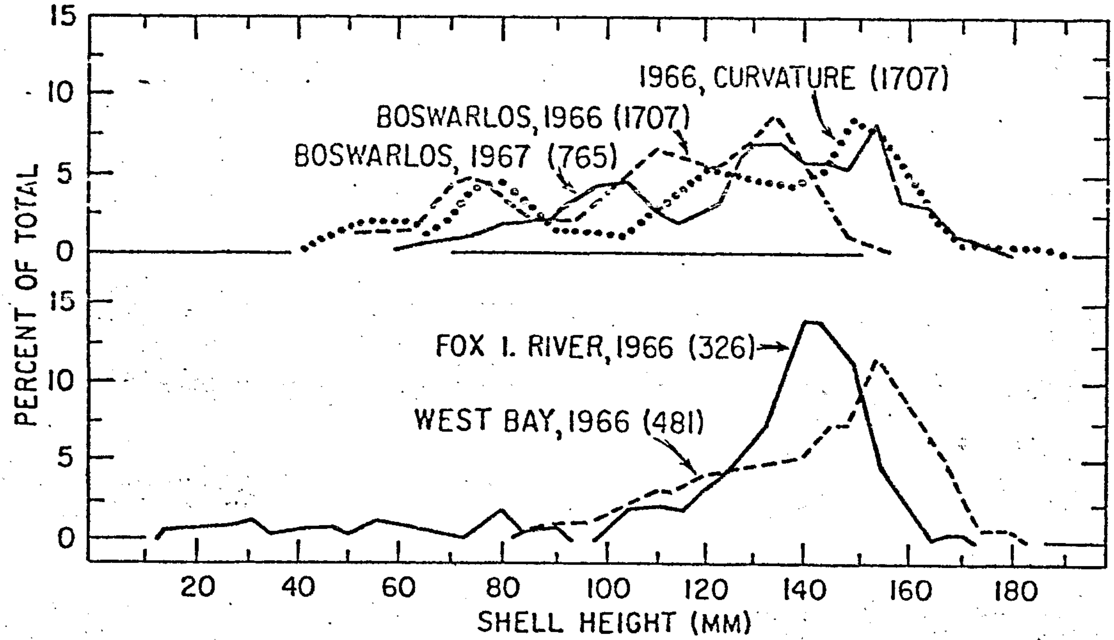

Fig. 3A-D. Shell-height frequencies of scallops from the three beds during 1966-67 (curvature measurements except as indicated). Numerals after the years indicate sample sizes.

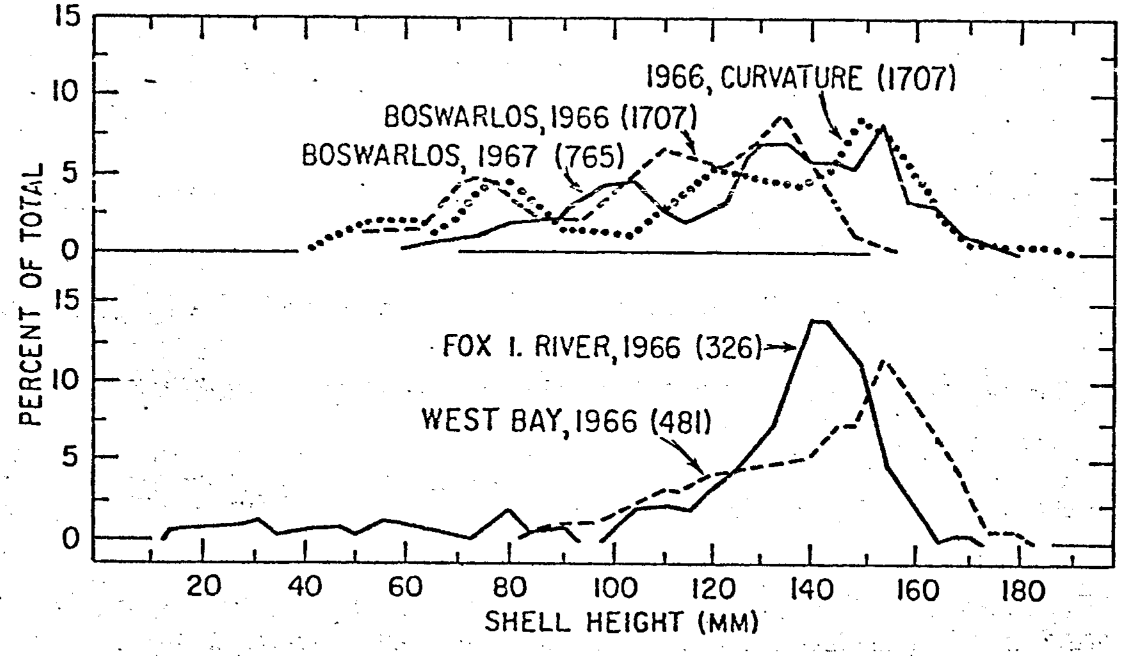

Fig. 3A-D. Shell-height frequencies of scallops from the three beds during 1966-67 (curvature measurements except as indicated). Numerals after the years indicate sample sizes.