IRISH FISHERIES INVESTIGATIONS

SERIES B (Marine)

No. 17 (1977)

AN ROINN IASCAIGH
(Department of Fisheries)

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THE GROWTH OF *MYTILUS EDULIS* FROM CARLINGFORD LOUGH

The growth of *Mytilus edulis* from Carlingford Lough

by

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Abstract

The growth of *Mytilus* at five stations in Carlingford Lough and two in Belfast Lough was calculated from annually produced growth rings.

These rings were shown to be annual from measurements of the seasonal growth of marked animals on the shore.

Shell : tissue ratios were found to vary from station to station.

Variations in growth are discussed in relation to sea temperatures, breeding cycles, salinity, pollution and level on the shore.

Introduction

The abundance and commercial importance of estuarine mussels have prompted many investigations to be made into various aspects of their biology. Most of these studies have been concerned primarily with growth and productivity, yet relatively little information is available on growth of the extensive stocks around the Irish coast. The present investigation was undertaken in order to examine in detail the growth of *Mytilus edulis* in the estuarine conditions of Carlingford Lough where a commercial fishery has been established.

Dry tissue and shell weights together with shell length have been used as parameters of growth in the present investigation, each having been related to the other to minimise the errors inherent to the different techniques. Direct comparisons of growth in different populations have been made and the influence of factors controlling growth examined.

Methods

Sampling stations were chosen along the northern shore of the lough at Greencastle, Killowen Point, Rostrevor and Narrow Water at the mouth of the Newry River (Fig. 1A), and at Holywood on the southern shore of Belfast Lough (Fig. 1B).

Three methods which provided information pertinent to the study of growth were used. Measurements of shell length were made in marked individuals kept on the shore. Winter rings or annuli provided a history of shell growth over previous years. Finally relationships were formulated between age, length and weight.

Measurement of shell length in marked animals

Between November 1968 and October 1969 marked individuals were used to determine the growth rates at four low shore stations. The number in each sample was restricted to 20 since the short exposure time prevented a larger number of measurements being made. The initial length of the shell ranged from 4.0 to 5.5 cm. Mussels were collected, numbered with a felt tipped pen and placed in cages at the same level of the shore adjacent to the beds.

Cages were made of 'Twyweld' wire mesh and measured 80 × 50 × 20 cm external dimensions. The walls were constructed of two layers of mesh spaced 5 cm apart to prevent predators attacking individuals close to the sides. As all the stations had sandy or muddy substrates the cages were anchored to concrete blocks.

The animals quickly attached themselves to the floor of the cages and to stones placed inside. The subsequent monthly measurements were usually performed without cutting the byssus attachments as the clusters of mussels could be inspected while still attached to stones.

The use of growth rings

Most of the mussels collected at stations in Carlingford and Belfast Loughs were characterised by distinct growth rings. The most conspicuous rings were assumed to be annual. This assumption was tested by comparing the annual growth increment between rings with shell growth as measured directly in animals kept in cages.

In order to construct growth curves by the ring method distances between rings in samples of over 100 mussels were measured. Large individuals provided the most comprehensive record since these have the greatest complement of winter rings. Estimates of growth by this method, therefore, tend to be maximal for each population. Variation between different age groups was minimised by measuring large numbers of animals of all ages in each population.

Length, age and weight relationships

Shell length and shell and tissue weights were measured in samples of 50 to 100 mussels, and related to age calculated by the annual ring method. Seasonal changes in weights were estimated from data on shell length increments of animals in growth cages. Weight and length were related by logarithmic plots, where k, the growth ratio, proved to be constant over the small size range examined.

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Results

Growth of Carlingford mussels

In November 1968 large samples were taken from the four low shore stations in Carlingford Lough. Ring number—the number of winter rings from the umbones—was plotted against shell length (Fig. 2). Since larval settlement is maximal during the summer months, the production of the first winter ring can be assumed to represent an age of approximately six months.

Growth was rapid during the first years of life but decreased with age. The crowding of winter rings made annual increments difficult to measure in old mussels, and it is probable that the ages of some individuals were far in excess of those recorded.

When comparisons are made between the four stations, the faster growing populations tend to show a sharper decrease in growth at an earlier age than those which are growing more slowly. Hence, each station may be identified with an optimal age and size range for growth. Furthermore, if Walford plots (Walford 1946) are used, as in Fig. 3, the maximum potential shell lengths for each population can be calculated (Table 1).

Table 1. The maximum shell length of mussels at the four low shore stations in Carlingford Lough as predicted by Walford plots.

Station	Theoretical maximum length (cm)
Greencastle	8.1
Killowen Point	9.0
Rostrevor	6.5
Narrow Water	5.9

In Fig. 4A and B shell weight and tissue weights were plotted against ring number to compare growth in biomass at the four stations. The resulting curves are sigmoidal, with rates increasing during early life and decreasing as the populations age. Insufficient numbers prevented a complete history of growth being compiled. It is again obvious from Figs. 4A and B that a size range for optimum growth exists for each population. The maximum growth rate in shell weight was recorded between ring 4 and 5 at Rostrevor, 5 and 6 at Killowen Pt. and Greencastle, and between 7 and 9 at Narrow Water.

A logarithmic plot was used to facilitate assessments of variation in shell and tissue growth. This is shown in Fig. 5 where in all cases k—the growth ratio—increased progressively as a result of the rate of shell deposition exceeding that of tissue growth. This increase was greatest during later life in stations with the smallest growth rates.

It must be stressed that information on shell and tissue applied in the above graphs was based on measurements taken during a single month. Fluctuations of shell and tissue weights in response to seasonal influences could cause radical changes in growth ratios. A more detailed knowledge of seasonal changes of these components is essential to ensure that general conclusions on proportionality and growth hold true.

It was impossible to compile a complete record of shell and tissue weights for all age groups at each station during the course of a year. A compromise was made by weighing tissue from animals of a shell length of 5 cm. This enabled changes in tissue weight to be observed while shell weight remained relatively constant. The results for the four low shore populations are given in Table 2, from which it can be seen that seasonal variations are quite pronounced. Weights were highest in early winter and declined to minima in May. By June, increases were recorded and this trend remained through to September when records were closed. An examination of the weight changes from station to station reveals that the general pattern was followed by all populations. Slight deviation did occur during certain months but this can probably be attributed to sampling errors. It may be concluded that the four stations parallel each other. Growth ratios, therefore, vary slightly during the year but comparisons between populations still generally hold true.

Factors influencing growth

The average absolute and relative growth rates of samples of marked mussels were plotted over the period from November 1968 to October 1969 (Fig. 6). Relative growth has been expressed as K—the instantaneous relative growth rate x 100.

$$\text{i.e. } K = 100k$$

$$\text{and } k = \frac{\log L_2 - \log L_1}{t}$$

where L_1 is the initial shell length and L_2 the length at time t.

Table 2. Seasonal changes in tissue weight in mussels from four low water stations.

Date	Dry weight of tissue (g)			
	Greencastle	Killowen Point	Rostrevor	Narrow Water
1968				
25 November	0.56	0.65	0.55	0.48
17 December	0.54	—	0.49	0.46
1969				
13 January	0.50	0.56	—	—
3 February	0.46	0.49	0.49	0.46
5 March	0.54	0.48	0.44	0.42
1 April	0.43	0.49	0.43	0.38
19 May	0.38	0.40	0.41	0.35
24 June	0.50	0.51	0.55	0.45
8 September	0.55	0.59	0.57	0.50

Total growth over the year in the marked samples in cages can be compared with that calculated from winter rings (Table 3). There is a significant correlation except at Rostrevor. The values indicate that growth increments over the past year were similar to those for previous years, and suggest that the growth rings are annual.

Small increases in shell length were recorded during the period from November to May. The increments were insignificant, however, when compared with the growth which ensued from June to September. Maximum growth rates were attained by June except at Rostrevor where growth was greatest in August. By November growth had ceased at Greencastle and Killowen Pt., while the cages were lost before records were completed at Rostrevor and Narrow Water.

Table 3. Comparison between annual shell increment in animals grown in cages and the increment calculated from annual rings.

Station	Annual linear growth of 5 cm mussels (cm)	
	Cages	Annual rings
Greencastle	0.17	0.20
Killowen Point	0.76	0.73
Rostrevor	0.24	0.41
Narrow Water	0.19	0.20

Even though significant differences were recorded both in the total annual increment and in seasonal growth rates throughout the year, seasonal temperatures varied little between stations. In Fig. 7 the instantaneous relative growth rate was plotted against day-degrees. A day-degree value is the product of the number of days between observations and the average sea temperatures during that period. Progression through the year is indicated by arrows. Relative growth increased with temperature but the relationship changed during the latter part of the year as temperature dropped This feature was found to occur at each station.

It can be seen in Table 2 that tissue growth does not have any direct relation with changes in temperature. Weight is at a minimum in May, the main period of spawning, and increases as recovery occurs. During the recovery period tissue growth parallels shell growth.

Stations with predominantly high salinities had higher growth rates, but where land drainage reduced salinities growth rates and maximum shell sizes were lower. Shell deposition was greatly reduced and tissue growth decreased rapidly at stations of low salinity. (Figs. 4A and B and Table 4).

Reduced salinity as found in the upper reaches of the lough brings with it associated conditions of reduced levels of plankton and increased silt and industrial pollution. Plankton and silt are factors which influence the rate of feeding and will be dealt with in a subsequent paper. An attempt was made to elucidate the effects of pollution in the field by examining growth in mussel populations at Holywood on Belfast Lough, where nutrient enrichment is at a high level while salinity is in excess of 30⁰/₀₀.

In Fig. 8 growth at Holywood followed the pattern already outlined for populations in Carlingford Lough. If shell and tissue weights are plotted against age (Figs. 9A and B) it is evident that the pattern of growth is comparable to that of the Carlingford populations, and growth rates are high approaching the highest rates recorded from Carlingford Lough.

Table 4. The mean, maximum and minimum salinities at the four low shore stations in Carlingford Lough (Nov. 1968 to May 1971).

Station	Salinity ⁰/₀₀		
	Mean	Maximum	Minimum
Greencastle	30.8	32.2	28.5
Killowen Point	33.2	34.0	32.4
Rostrevor	32.5	34.1	29.5
Narrow Water	15.1	22.5	13.2

Not least amongst the controlling factors of growth in littoral mussels is that of exposure to air. In Fig. 8 it is evident that growth is slower in middle shore mussels than those experiencing shorter periods of emersion. Shell weight increased exponentially in the lower shore station but declined rapidly on the mid shore (Fig. 9A). This decline was less marked in tissue weight and mussels from both levels showed a gradual decrease in tissue growth later in life. When shell and tissue weights are plotted together shell growth is greater in the middle shore than on the lower shore for animals of the same tissue weight.

Discussion

In *Mytilus edulis* longevity is determined by the conditions in which the animal occurs rather than as a result of intrinsic changes in the physiological balance within its organisation. Segerstråle (1960) has pointed out that considerable variations in the life span can exist in some species depending on their environment. In *M. edulis* estimates of longevity vary from 7 to 9 years (Dragoli 1966) to 17 or more years (Seed 1969). In the present investigation maximum ages were in excess of 10 years. As methods of ageing valves depend extensively on characteristics produced during shell growth such as annual rings and ligament scars, and as it is often impractical to follow animals through their life, estimates of life spans can only be tentative.

While it was not possible to calculate maximum ages, each population can be identified with a maximum shell length or body weight. If the environmental regime is assumed to remain constant, however, limitation in size must be due to changes in the organism as it grows. Zeuthen (1944) and Jorgensen (1952) recorded decreasing metabolic rates per unit weight with increasing sze in *M. edulis*, while von Bertalanffy (1950) proposed that the rate of metabolism is proportional to the $\frac{2}{3}$ power of weight in lamellibranchs. Conversely, Segerstråle (1960) cited examples of artificially reduced metabolic rates causing prolonged and stunted growth in invertebrates. The environmental conditions at each station undoubtedly control metabolic rates. Slow growing mussels reached a smaller size limit over a longer period compared with faster growing individuals which attain their higher metabolic limits rapidly.

In such considerations of growth a distinction must be made between the two major components of the body: the shell and the tissues. While calcium can be taken up from the gut it can also be absorbed from seawater by mantle cells and deposited in the shell (Bevelander and Benzer 1948; Rao and Goldberg 1954; Jodrey and Wilbur 1955). Andrews (1961) suggested that the large volumes of water passing over the tissues during feeding provide ample opportunity for direct diffusion and absorption of calcium salts. Fox, Sverdrup and Cunningham (1937), Jorgensen (1949) and Theede (1963) have demonstrated that filtration in feeding is inversely proportional to size. It would seem, therefore, that the greater filtration rates per unit weight and their prolongation in stunted populations as at Narrow Water and Rostrevor produce a proportionally greater calcium uptake. This caused a more rapid increase in the growth ratios of these mussels in later life than in the faster growing populations at Greencastle and Killowen Pt., where feeding conditions are more favourable and filtration rates rapidly diminish with age.

Tissue growth is closely related to the seasonal changes in its composition. Bruce (1926) showed that the rate of oxygen consumption in *M. edulis* varies seasonally with a maximum in June and July and a minimum in November to January, suggesting a correlation between growth and temperature. Kruger (1960), on the other hand, demonstrated a high rate of oxygen consumption in March and a reduction in July, which corresponded to variations in the protein content of the tissue. Berg, Lumbye and Ockelmann (1958) concluded that oxygen uptake was associated with gonad development. In the present investigation tissue weight dropped gradually during the early part of the year and increased after spawning, reaching a maximum in the autumn. Hence, any expression of tissue growth includes the large variable component of reproductive tissue, and this tends to obscure responses of other tissues to the environment.

In comparisons between shell and tissue ratios it was found that the ratios increase more rapidly in later life in slow growing populations. Absolute values of the growth ratio must be considered in the light of the peculiarities of the conditions in which growth occurs at each station.

Coe and Fox (1944) in their study of the ecology of *Mytilus californianus* came to the conclusion that growth in molluscs increases with temperature to a certain optimum and thereafter decreases. Bayne (1965) found that the optimum temperature for growth in *M. edulis* larvae was dependent on the place of origin of the larvae. The rate of shell deposition in the Carlingford mussels showed considerable variation in response to seasonal temperature fluctuations as the year progressed. Acclimation to higher temperatures probably plays an important role in this variation as shell growth tended to be slower as the temperature was decreasing than when it was increasing.

Milne (1940) has pointed out that in the upper reaches of estuaries mussels will be found on banks but not on buoys where fluctuations in salinity are greater. In mussels exposed to sharp drops in salinity Malone and Dodd (1967) found a lower threshold for calcification between 14.7 and 20.0⁰/₀₀, while shell deposition is known to occur in mussels acclimated to 5⁰/₀₀ (Schlieper, 1957). It seems reasonable to conclude that low salinities reduced shell growth at Narrow Water and Greencastle. In addition the low values of the shell to tissue growth ratios at these stations are further indications that low calcium levels in the medium influence growth. Hence the salinity regime at Narrow Water and Greencastle leads to a reduction in the growth rate, final size and the ratio of shell to tissue weights.

The present study has been restricted to littoral populations of mussels which depend on periods of immersion for feeding and respiration. In comparisons made between middle and low shore stations growth was slower in those populations from the middle shore. This is to be expected as food intake is reduced and growth diminished in these localities. Baird and Drinnan (1957) have demonstrated that shell weight increases and tissue weight decreases in mussels of similar length as the shore is ascended. Rao (1953) suggested that reduction in the time available to absorb calcium ions—the period of immersion—reduced shell deposition. Hence, during the same time interval populations higher on the shore deposit less shell than low shore mussels. However, shells of similar length from the two levels as used by Baird and Drinnan represent two populations of different ages. Therefore, it is more meaningful in discussing comparative proportionality of body components to use animals of the same age. Results from Belfast Lough populations showed that shell and tissue weights were lower in animals from the mid shore, but the ratio in these animals was higher than in mussels of the same age from the low shore.

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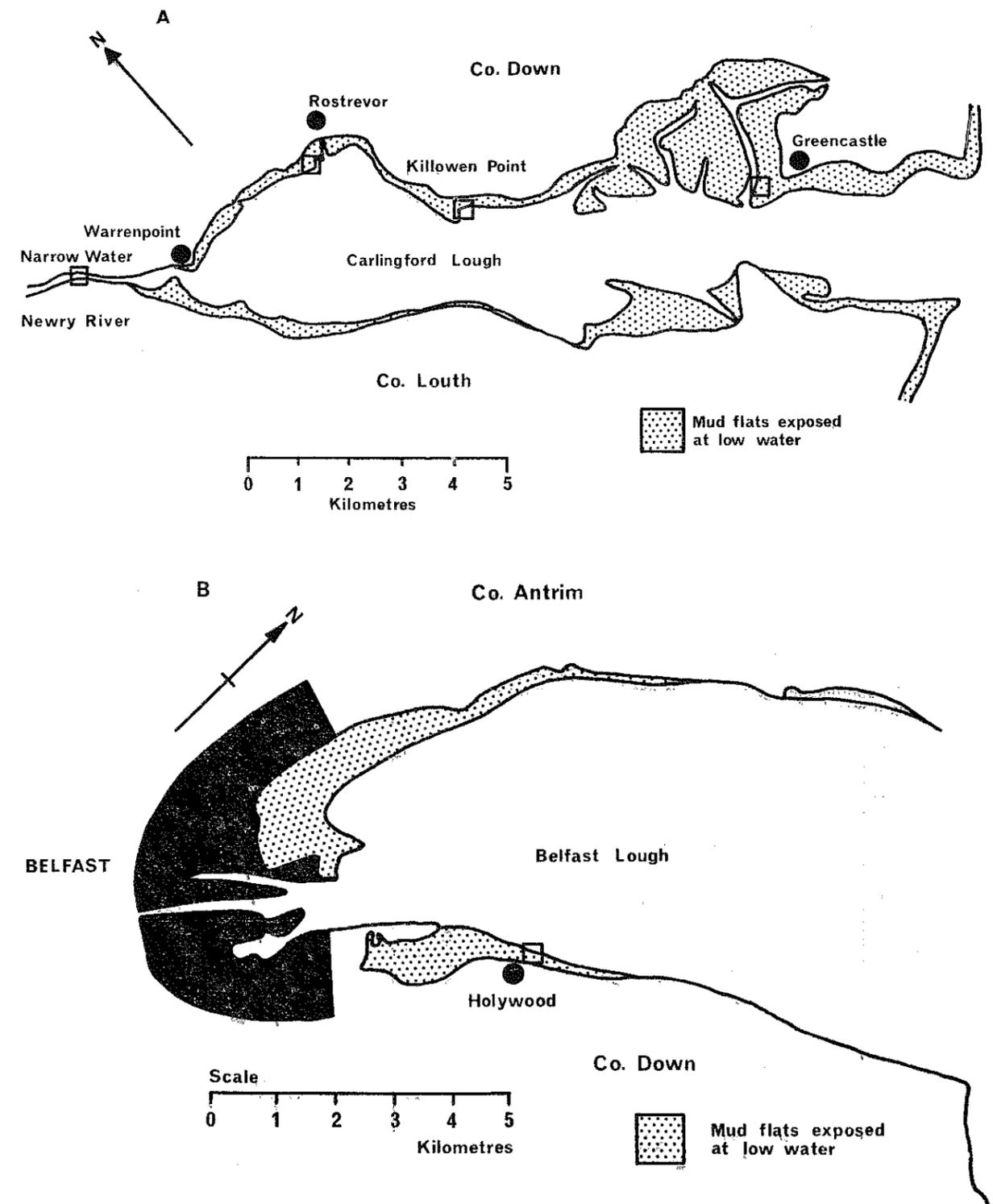
Fig. 1. Sampling stations in Carlingford Lough (A) and Belfast Lough (B).
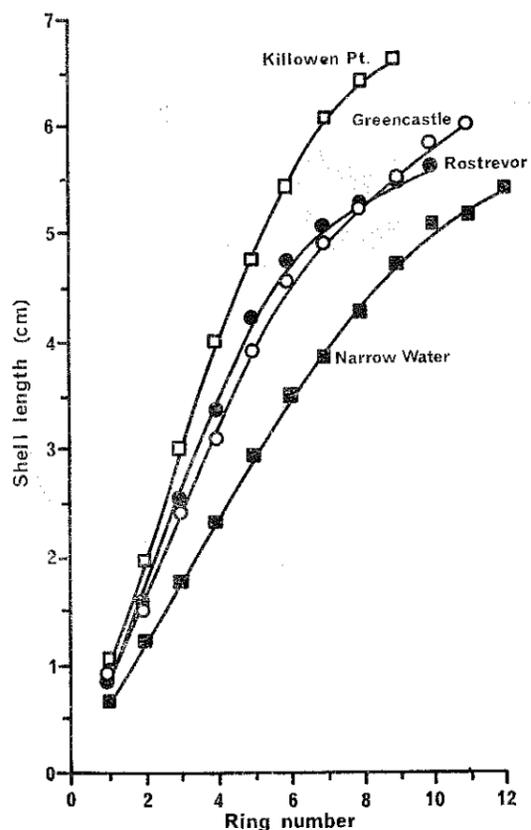
Fig. 2. Growth rates of low shore populations of *M. edulis*. The appropriate age in years is obtained by subtracting 6 months from the ring number.
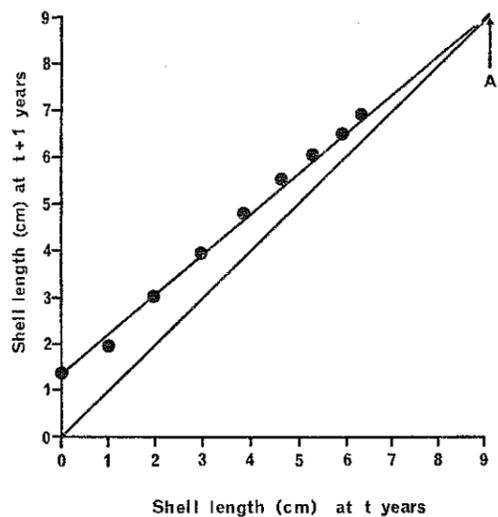
Fig. 3. Walford plot of the growth of low shore mussels at Killowen Pt.

A is the predicted maximum size.
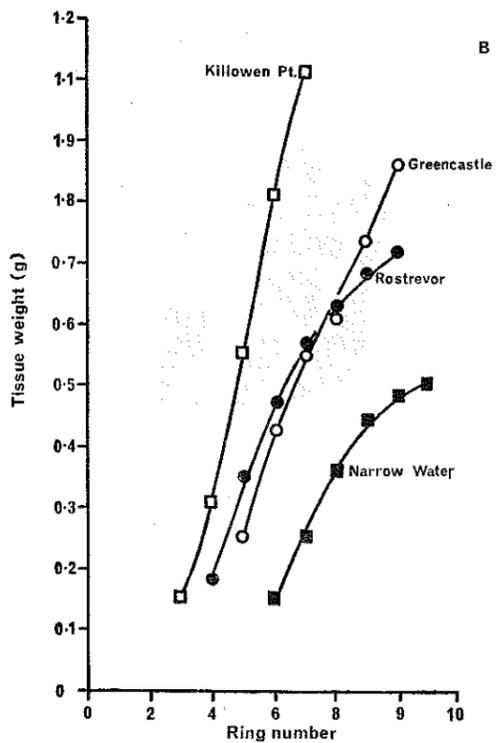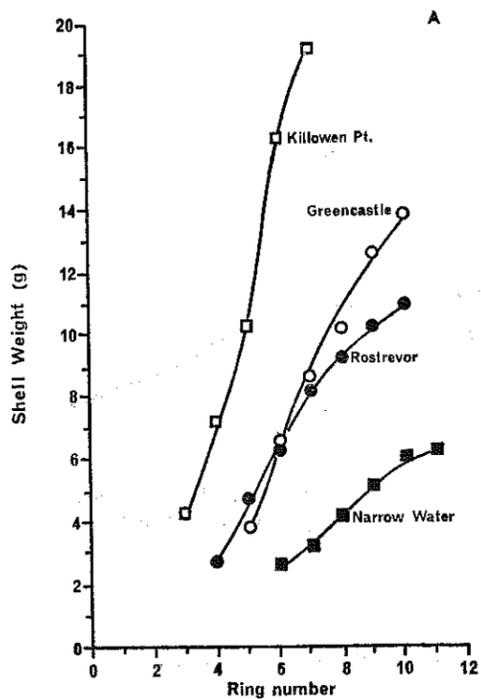
Fig. 4. The relationship between shell weight and ring number (A) and tissue weight and ring number (B). (Nov. 1968).
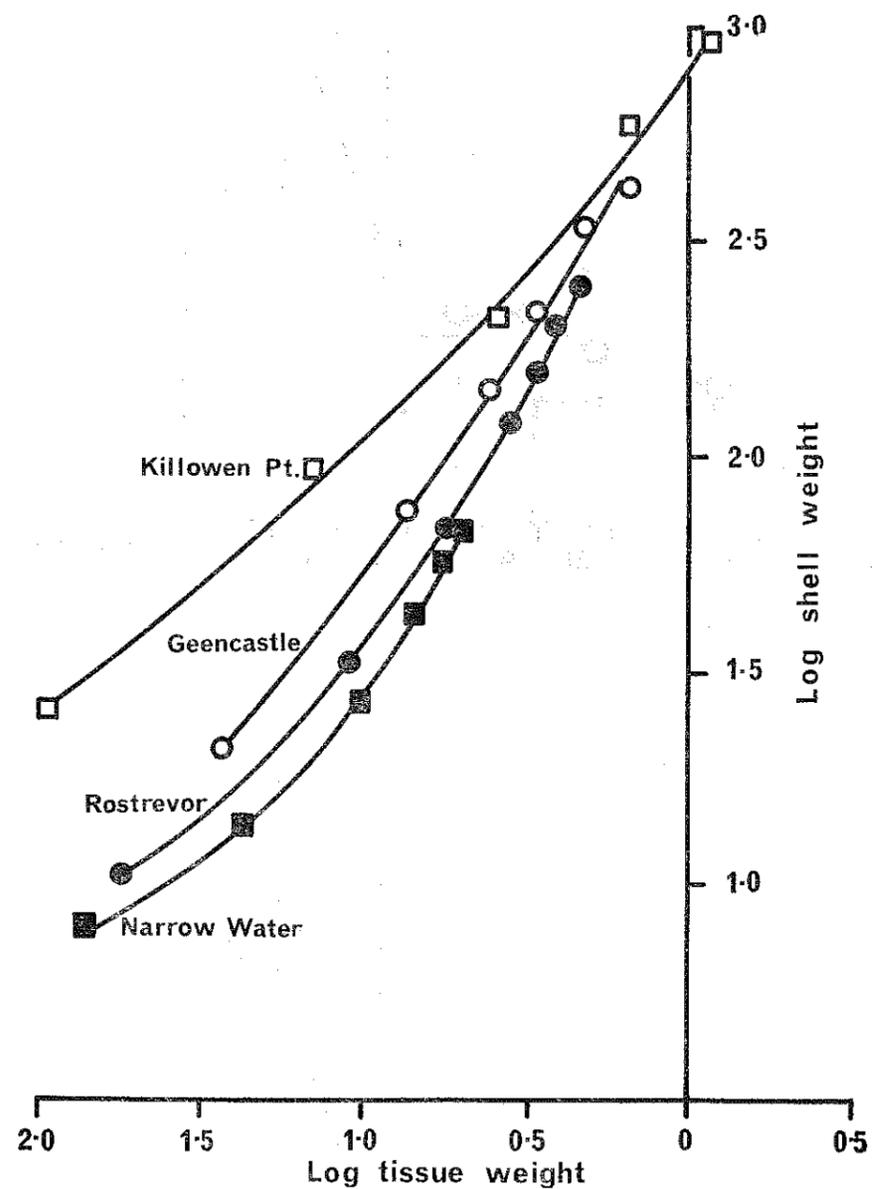
Fig. 5. The relationship between shell and tissue weight in four low shore populations (Nov. 1968).
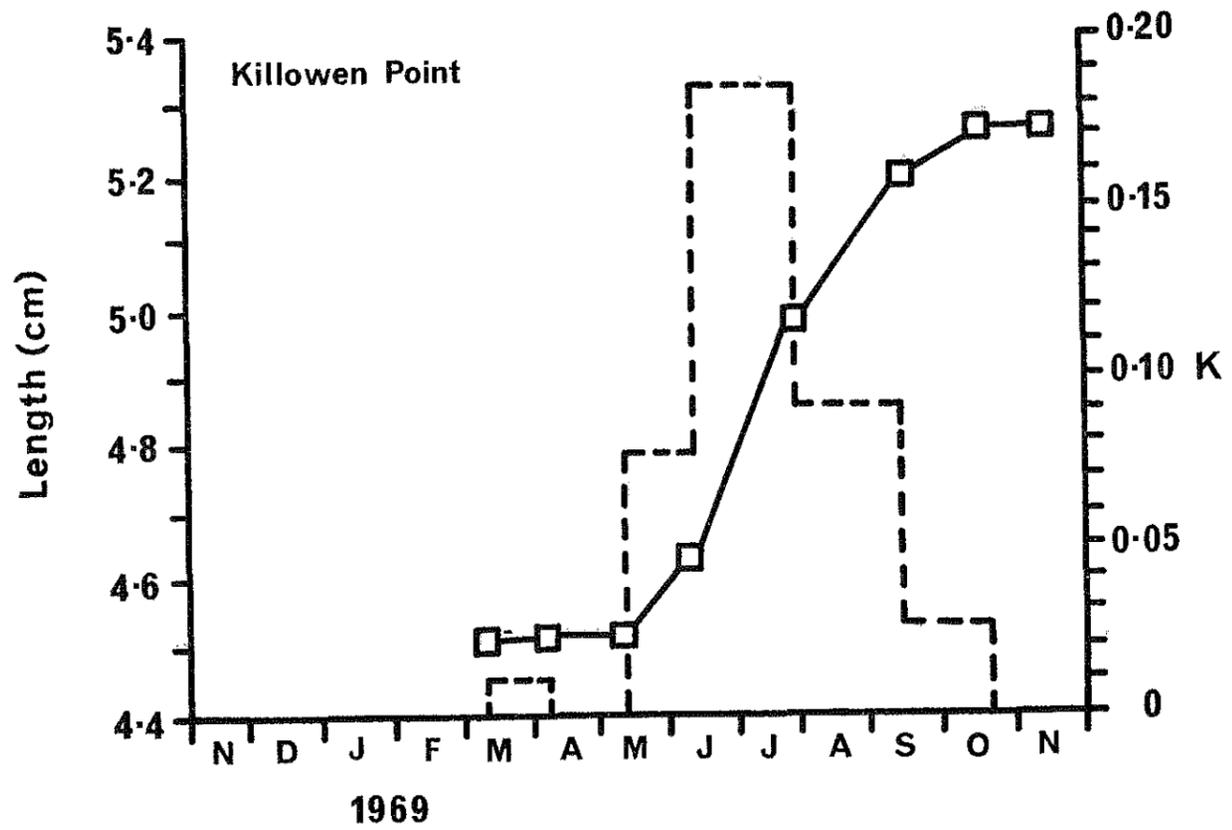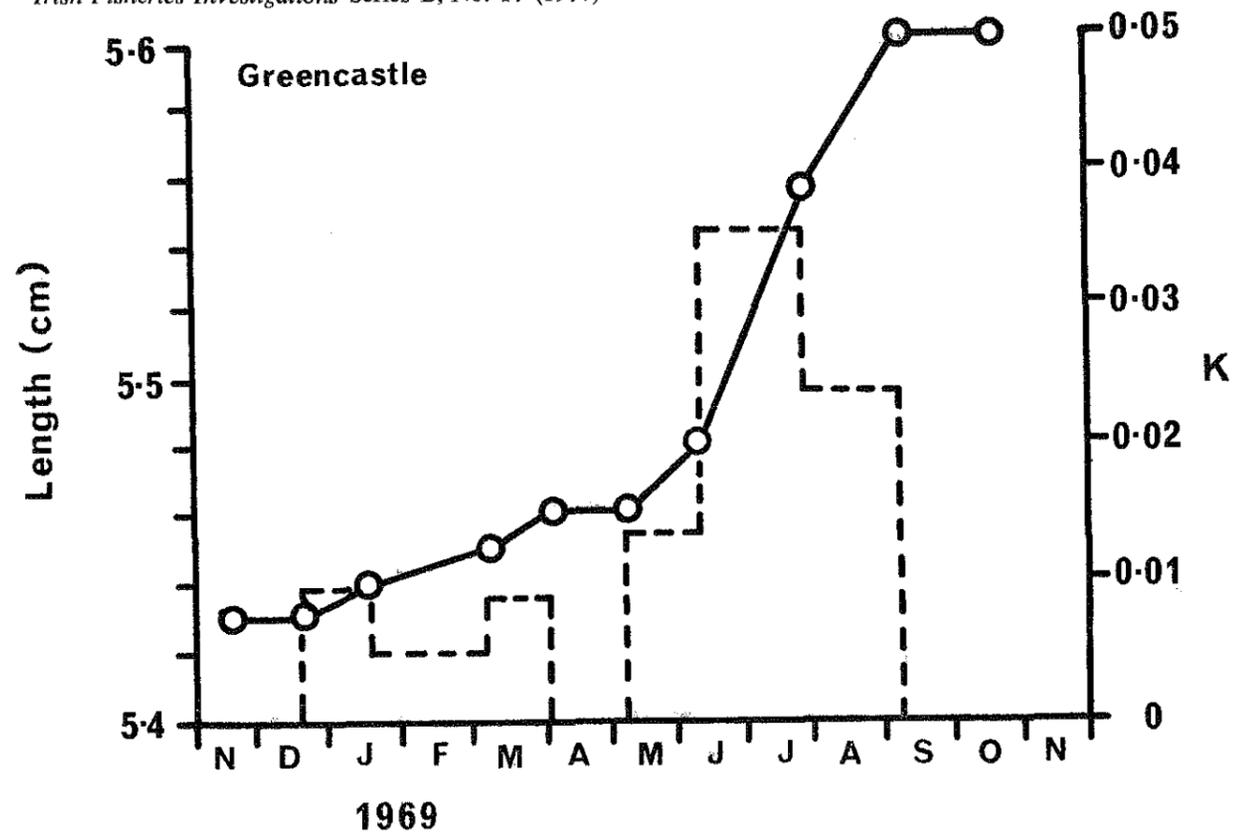
Fig. 6. The mean absolute and instantaneous relative growth rates of mussels in cages during 1969.
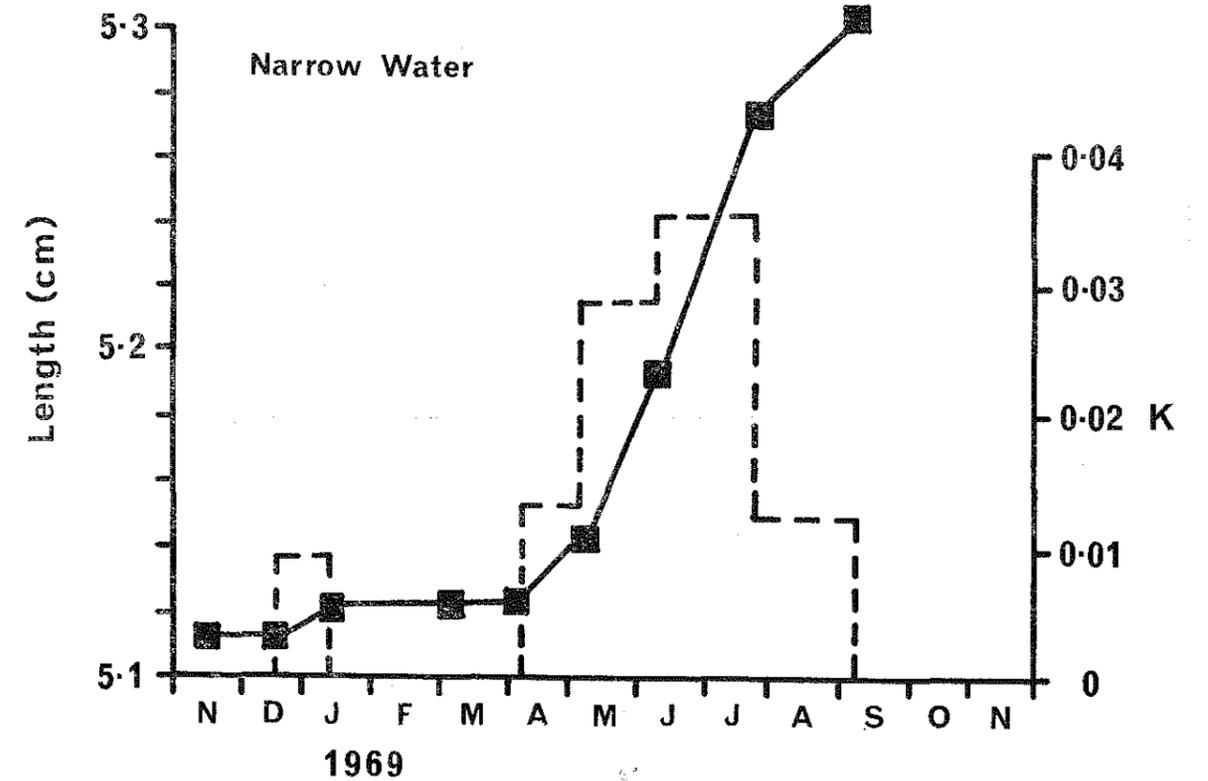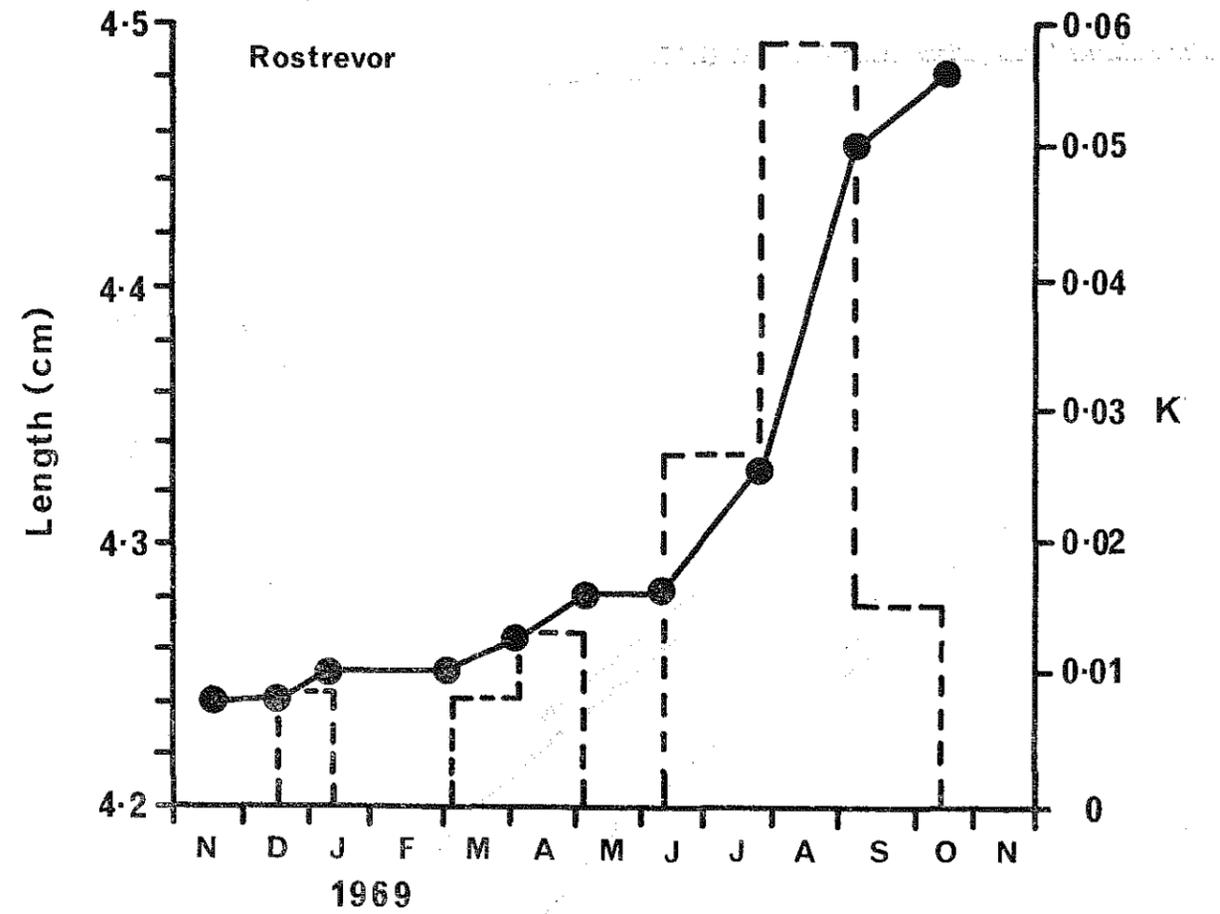
Fig. 6 (continued). K is represented by the broken line.
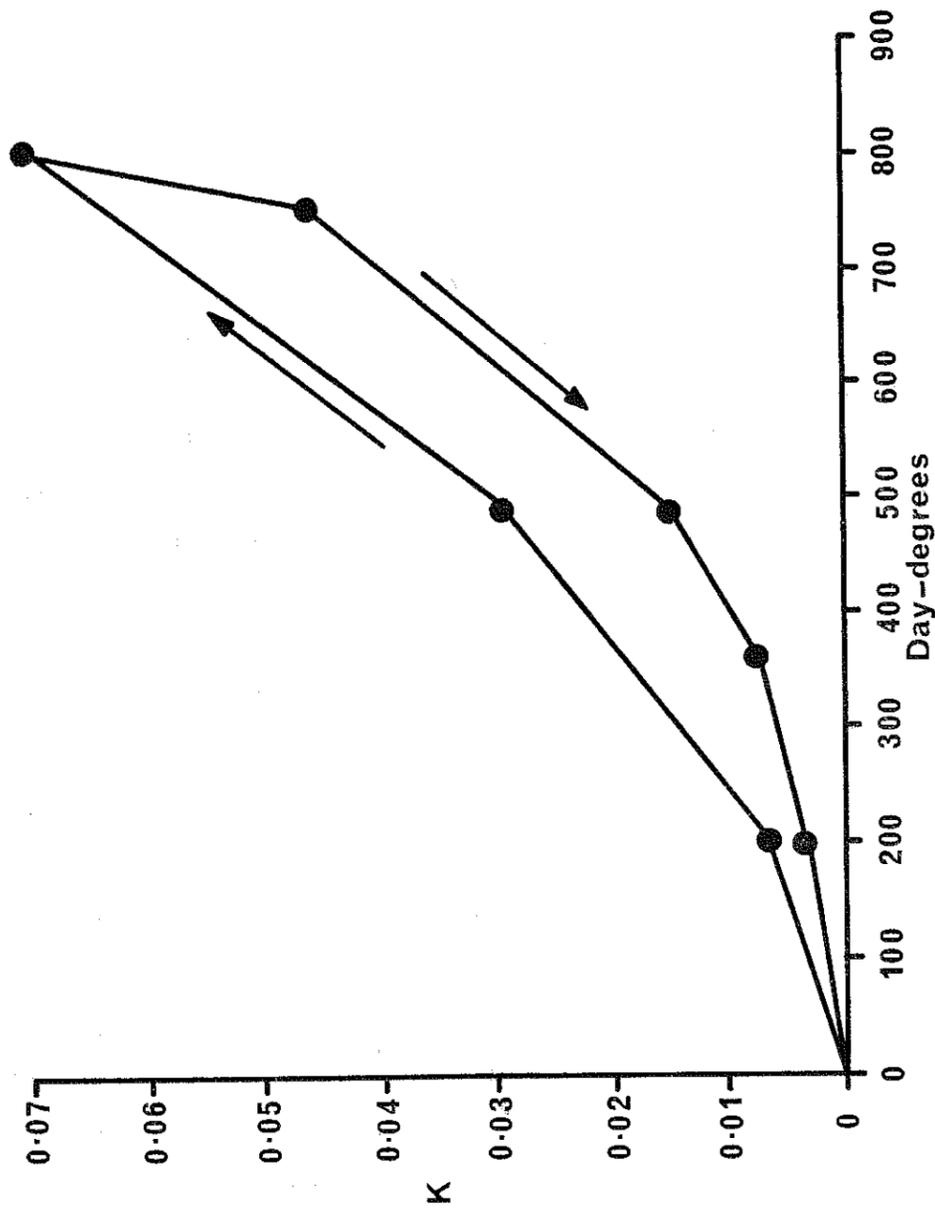
Fig. 7. The relative rate of linear shell growth as a function of day-degrees. Relative growth is expressed as the instantaneous relative growth rate × 100, K. Arrows indicate periods of increasing and decreasing day-degree values.
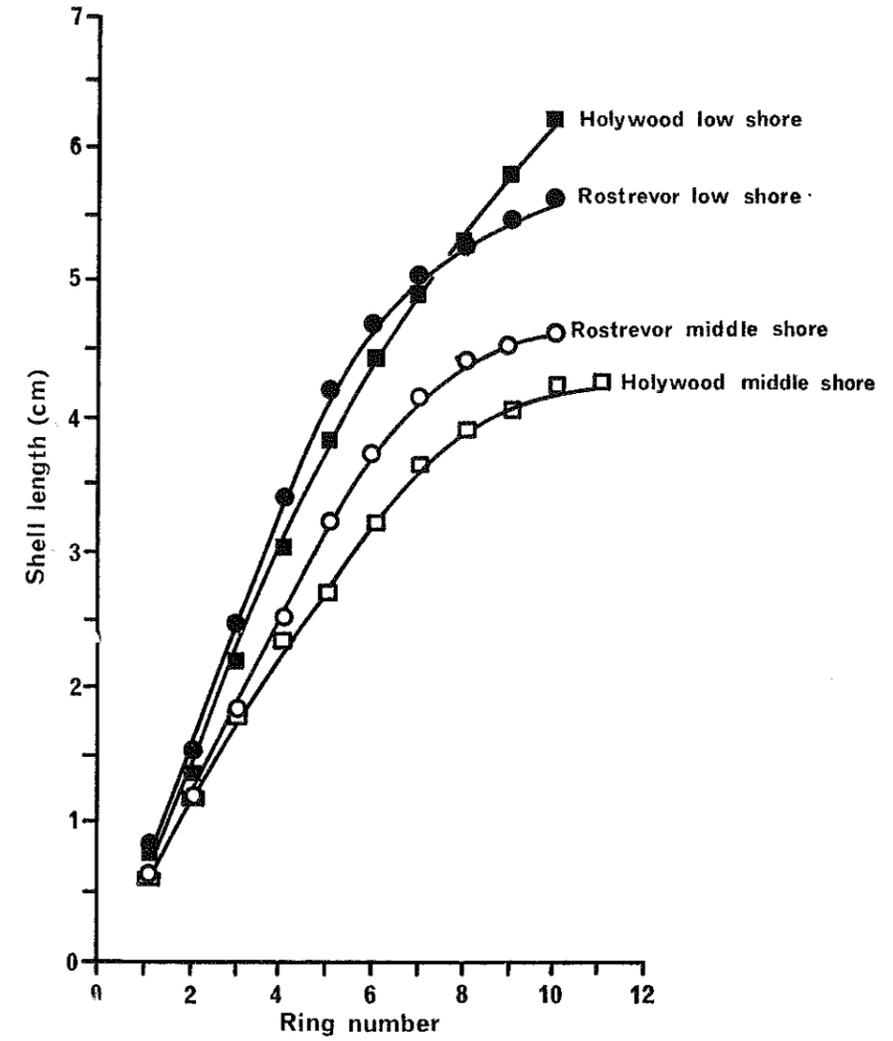
Fig. 8. Relationship between shell length, age and tidal level.
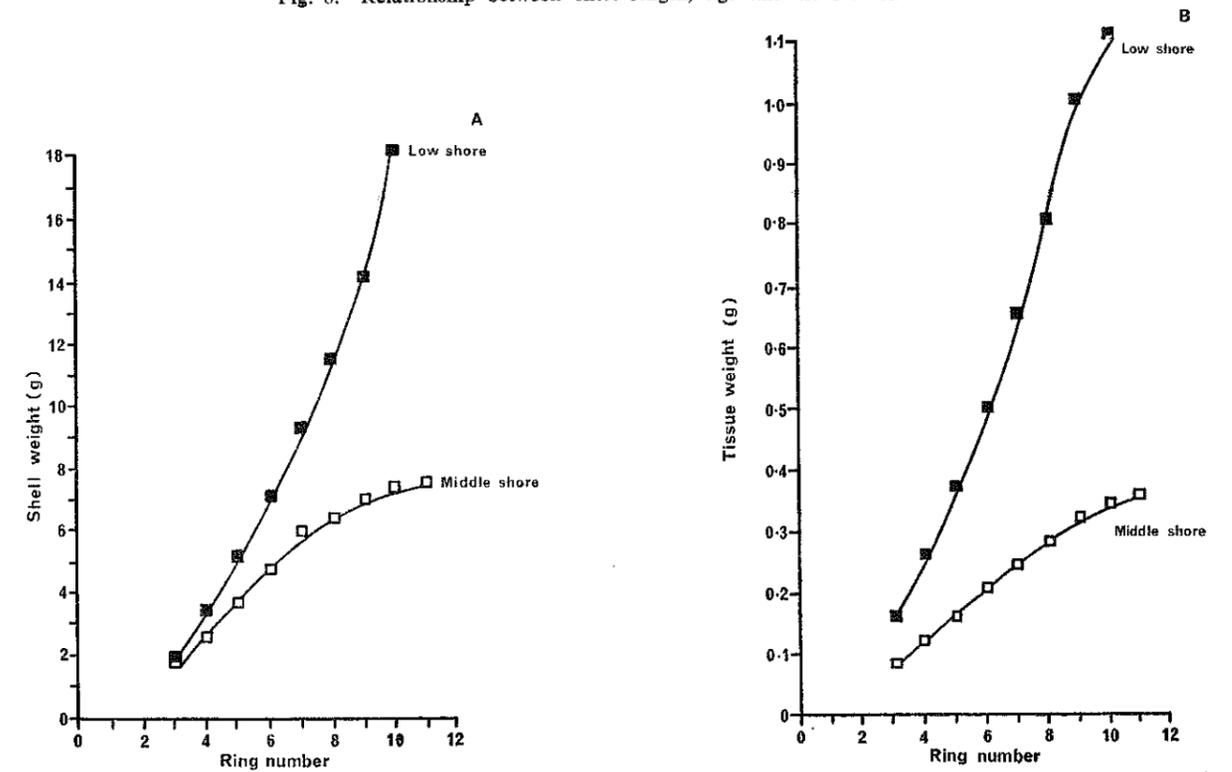
Fig. 9. Growth rates of low and mid shore populations at Holywood expressed as shell weight (A) and tissue weight (B). (Oct. 1970).

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IRISH FISHERIES INVESTIGATIONS SERIES B (MARINE)

Irish Fisheries Investigations Series A (Freshwater) deals with scientific research into all aspects of freshwater fisheries.