International Council
for the Exploration of the Sea

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Fisheries Improvement Committee
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Summary

Cultivation of mussels on ropes suspended from rafts and floats has been successfully carried out in Loch Tournaig and Linne Mhuirich, inlets on the west coast of Scotland. Conditions in L. Mhuirich, which is less deep and has a narrow entrance from Loch Sween with a shallower sill, appear to be especially favourable. The tidal range is only some 2-3 ft (0.6-0.9 m). Summer temperatures are much higher than those of the adjacent open sea, reaching 20°C. Salinities are fairly high, generally 30-32‰ and never below 25‰.

As a result of the conditions mussel spat are abundant and their growth is very rapid. Settlement occurs chiefly in the summer, resulting from a spawning in spring. Ropes hung in the spring of 1966 acquired a heavy settlement of spat in July, heavier on rougher natural fibres than on the smoother synthetic "Courlene". By September 1967, only 14 months later, they had reached an average size of 67 mm (2⅔ in.) and were almost all marketable. This rate of growth is exceptionally high, approaching that obtained in the highly organised industry in northern Spain. Their flesh content was high and the shell thin. Within 18 months after settlement a rope 10 ft (3 m) long should yield at least ½ cwt (25 kg) of mussels, probably more.

Mussel cultivation has now commenced in Linne Mhuirich on a commercial scale. Similarly favourable conditions almost certainly exist in other inlets on the west coast of Scotland. There appear to be good prospects that Scottish mussels of excellent quality could satisfy a part of the large British demand for mussels.

Introduction

There is a great demand for mussels for human consumption in Britain. They are gathered and cultivated in England and Wales, but in order to satisfy the demand something like £200,000 worth (50,000 cwt) are imported each year, chiefly from Holland and Denmark. Mussels are common round the Scottish coasts, and indeed there was a thriving fishery in the 19th century. Almost all the 12,000-14,000 cwt which are now gathered annually go for bait in line fishing, and few are for human consumption. Generally speaking, the quality of mussels on Scottish shores has been at best only just good enough for the human market and often it is very poor through overcrowding, long exposure between tides, silty water or other unfavourable conditions. Usually the beds consist of blue-black mussels with rounded edges, indicating slow growth. These are in marked contrast to the brown, sharp-edged shells and plump flesh of fast-growing mussels. Since mussels lend themselves well to economic cultivation, experiments were commenced to determine whether it would be possible, by suitable methods, to produce in Scotland a good quality mussel capable of satisfying a part of the British demand.

Cultivation on Ropes

The various methods of cultivating mussels at present in use have been recently described by Iversen (1968). Cultivation on ropes suspended in the water has long been carried out on the Mediterranean coasts of southern Europe. Recently, however, there has arisen a flourishing industry based on this method on the Galician coast of northern Spain (Andreu, 1958; Paz-Andrade and Waugh, 1968). This has resulted in a great increase in the Spanish production of mussels, which in 1966 reached 64,000 tons, 60,000 tons of them from the Galician coast. A large proportion of these is exported to France.

In the rias (river valleys which have become flooded by the sea) of the Galician coast, there are now some thousands of rafts in use, with an average of 800 ropes hanging from each. Mussels are prevented from sliding off the ropes by sticks pushed through the lay of the rope. By October, some 5 months after settlement, the mussels have reached a size of 30-40 mm, and they are 75-80 mm long and ready for marketing by the following summer, at most only about 14 months after settlement.

The method of rope cultivation as practised in Spain has a number of advantages over other systems. It is simple; the phytoplankton on which the mussels feed is used at all depths of the water and not only on the sea bed; the mussels are removed from predators on the sea bed (e.g. star-fish and crabs); there is less chance of bombardment of the mussels by silt than on the bottom and so the growth-rate is enhanced; and the mussels are covered by water at all times and not just when the tide is in. Furthermore, in areas where the parasite Mytilicola is present, the risk of infestation is reduced by rope cultivation, since the mussels are raised above the bottom.

The Scottish Experiments

In addition to a high plankton production, one of the factors in achieving such a high growth rate in the Spanish rias is the high temperature, which in the summer reaches 20°C and generally does not fall below 10°C in the winter (Andreu, 1958). The sea temperatures in the latitudes of Northern Europe are generally lower. It is known, however, that in parts of some Norwegian fjords conditions are such, with temperatures locally high in the summer, that mollusc cultivation can be carried on there (Gaarder and Bjerkan, 1934; Bøhle and Wiborg, 1967). It seemed that in Scotland similarly suitable conditions, with the temperature rising above that of the nearby open sea in the summer even though it might be correspondingly lower in the winter, would be most likely to occur in certain inlets on the west coast. The west coast has the added advantage that, except for parts of the Firth of Clyde, the mussels occurring there are free from Mytilicola.

Loch Tournaig

Preliminary experiments to obtain experience of the technique were carried out in Loch Tournaig, off Loch Ewe, Wester Ross, not because the conditions are especially favourable there, but because research facilities were available at the nearby field station on Loch Ewe. Sisal ropes, 10 ft (3 m) long and 2½ in. (6.3 cm) in circumference, were suspended from a buoyed headrope in Loch Tournaig in March 1966. The first settlement of mussel spat on them occurred in June-July; by the first winter they had attained sizes of up to 38 mm (1½ in.) with a mean of 28 mm (> 1 in.) and by the second winter up to 66 mm with a mean of 44 mm.

Mussels of the 1965 settlement which were tied on to ropes and suspended in Loch Tournaig in May 1966, grew from a mean size of 31 mm then to one of 45 mm in May 1967 and one of 55 mm in May 1968. The flesh of these mussels was good, attaining a condition factor (wet meat volume/total internal shell cavity volume; see Baird, 1958) of 50%; 40% would be considered just acceptable. This suggests that it is possible to grow mussels to a commercial size of 2-2½ in. (50-63 mm) in Loch Tournaig in three years, considerably faster than recorded previously for naturally-growing mussels in Britain (see below, p. 4).

Linne Mhuirich

Linne Mhuirich, Argyll, was chosen as the principal site for the experiments, because conditions there were known to favour growth and breeding of the European flat oyster, Ostrea edulis L. (Millar, 1961). These experiments are being carried out by kind permission of Mr T.P. Stevenson, who holds the fishing rights in Linne Mhuirich.

Linne Mhuirich (Fig. 1) is a shallow, sheltered inlet $2\frac{3}{4}$ miles (4.4 km) long and up to $\frac{1}{4}$ mile (0.4 km) wide, with an even shallower sill and narrow entrance from Loch Sween. The tidal range is only 2-3 ft (0.6-0.9 m). Millar (1961) found that as a result of these conditions summer temperatures are relatively high. Temperatures reached 20°C in June 1967 and fell to 2.5°C in January 1968. Salinity is fairly high (generally 30-32‰ and never falling below 25‰) and there is no risk of pollution. The appearance of plankton samples taken in the inlet suggests that there is at times a high production of phytoplankton. Studies of chlorophyll and total carbon are currently being made to estimate the production there.

Methods

A few sisal ropes and courlene netting sleeves hung in Linne Mhuirich at the end of May 1966 acquired a dense coating of mussel spat in July, resulting from a spawning in the spring. These mussels were sampled at intervals of one or two months to assess the rate of growth and flesh condition.

The work was extended in the spring of 1967, when sisal ropes 10 ft (3 m) long and $2\frac{1}{2}$ in. (6.3 cm) in circumference, with five 8 in. (20 cm) sticks approximately $1\frac{1}{2}$ ft (45 cm) apart were hung from rafts and fleets of buoys. Each rope was easily detachable so that it could be weighed regularly. Rafts, on which ropes were attached about a foot above the surface of the water, proved more reliable than buoys, owing to movement of the buoys on the surface causing chafing of the ropes. Ropes have been removed at intervals to study the growth and condition of the mussels. Further ropes were put out and removed at intervals of one or two months in order to study the seasonal settlement of spat. In addition four types of rope were compared as to their suitability for mussel settlement.

Settlement of Spat

Settlement occurred at all depths on the ropes. The ropes and netting sleeves hung in May 1966 acquired a dense coating of mussel spat by July. In 1967 the seasonal pattern of settlement was studied by means of the ropes put out and removed at intervals of time from March onwards. Spat were first seen in June and settlement reached a peak in July-August, after which it fell away and had virtually ceased by October. No further spat was then observed until May 1968, presumably resulting from the spring 1968 spawning (Table I).

Four ropes each of four different kinds, $2\frac{1}{2}$ in. courlene, $2\frac{1}{2}$ in. coir, $2\frac{1}{2}$ in. sisal and 1 in. sisal were compared as to their suitability for settlement. This was shown by the weights of the ropes and contents in water, the increase in weight being attributable almost entirely to mussels. The best settlement occurred on coir, the roughest rope, and the worst on courlene, the smoothest (Table II). It is interesting that the primary settlement of spat occurred on hydroids and filamentous algae on the ropes as well as on the rope fibres, so that a prior settlement of these might well help the settlement of mussels.

Growth (Fig. 2)

The growth rate of mussels in Linne Mhuirich has been even higher than that in Loch Tournaig. After settlement in the summer, growth of the mussels is rapid during the summer and early autumn but slows down or

stops during the winter. It speeds up the following spring and summer and again slows down or stops in the autumn. It was possible from length-frequency data to identify the mussels of each main settlement and to separate them from the few that settled subsequently.

By January 1967, eight months after the first ropes were put out and six months after settlement, the mussels of the 1966 brood formed a mass almost a foot (30 cm) thick. The mean size of the mussels was 43 mm and the largest was 57 mm ($2\frac{1}{4}$ in.), already marketable size. By July 1967, one year after settlement, they measured up to 70 mm with a mean of 61 mm, and by September 1967, only 14 months after settlement, they measured up to 75 mm (3 in.) with a mean of 67 mm ($2\frac{2}{3}$ in.) and were almost all marketable. The growth of the mussels of the 1967 settlement has been similar - they had achieved a mean size of 41 mm by the time growth stopped in their first winter (Fig. 2).

These growth rates are far greater than any recorded for naturally occurring mussels in Britain, and compare favourably with those recorded anywhere in Europe except possibly those of the Galician rope-grown mussels (Table III).

Condition and Yield

The mussels grown on ropes in Linne Mhuirich had all the appearances of quick growth, a thin brown shell with a sharp edge and excellent flesh condition. The condition factor of the 1966 brood (Fig. 3) reached a peak of 60% in May 1967, fell to a minimum of 40% in June after spawning, had risen again to 63% by November and remained high until the following spring (1968). Spawning then occurred and it fell to 35% before recovering again. Thus, once the mussels had attained commercial size (say 60 mm) at the age of one year, they remained, except for a short time after spawning the following spring, in a condition acceptable to the market.

Some indication of the exceptionally good meat yield can be obtained from the figures for November 1967 when the condition factor was at its highest. Then, a sample of 20 mussels, with a mean size of 66.8 mm and a mean overall weight of 31.0 g, yielded an average of 13.0 g wet flesh (9.0 g when cooked) per mussel and the mean shell weight was only 10.5 g.

It has not so far been possible to obtain a measure of the total yield of mussels one might expect from a rope 10 ft long. We had hoped to do this in the autumn of 1968, but this might not be possible owing to eider ducks having stripped mussels from many of the 1967 ropes in April 1968. Anti-duck nets have now been placed round the rafts to protect those which remain. Estimates based on sample lengths of rope suggest that the total yield should be at least $\frac{1}{2}$ cwt (25 kg) of mussels, probably more, within 18 months of settlement.

Discussion

The suspended culture method of rearing mussels on ropes is well suited to the west coast of Scotland. Conditions in Linne Mhuirich, especially, favour the settlement and rapid growth of mussels, and the production of flesh of excellent quality. It is possible to produce there within 14 months a mussel eminently suitable for the human market. It is certain that other suitable areas will be found among the many inlets of the west coast. Examples of possible sites are Loch Creran, Little Loch Roag, Pool Roag and a number of small inlets on the west coast of Sutherland. Millar (1961) lists a number of areas which should prove suitable for growth and fattening of oysters, and they might well prove suitable also for mussels. The west coast of Scotland should be able to produce mussels of excellent quality capable of satisfying at least a part of the great demand for mussels which exists in Britain. Indeed, an encouraging start has been made with a pilot commercial production scheme in Linne Mhuirich, involving more than a thousand ropes.

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TABLE I

The Seasonal Settlement of Mussel Spat

Date ropes put in water	Date ropes removed	No. of weeks in water	No. of ropes	No. of spat (0-4 mm) per rope
28. 3.67	11. 5.67	6	3	0
11. 5.67	22. 6.67	6	4	81
22. 6.67	21. 7.67	4	4	90
21. 7.67	29. 8.67	5½	4	850
29. 8.67	23. 9.67	3½	4	115
23. 9.67	22.10.67	4	4	27
22.10.67	19.11.67	4	4	1
19.11.67	21. 1.68	9	3	0
21. 1.68	16. 3.68	8	4	0
16. 3.68	14. 5.68	8½	2	223

TABLE II

Mean Increase in Weight of Ropes in Water Attributable to Mussels, 21st July-23rd September, 1967

Rope	Increase (kg)
2½ in. coir	2.60
2½ in. sisal	2.19
1 in. sisal	1.43
2½ in. courlene	1.37

TABLE III

Comparison of Mussel Growth Rates

Locality	Method of growth	Growth rate	Authority
Galicia (Spain)	Ropes	(70 mm in 1 year / 80 mm in 14 months)	(Andreu, 1958)
Linne Mhuirich (Scotland)	Ropes	(61 mm in 1 year / 67 mm in 14 months)	(Present paper)
Oslo Fjord (Norway)	Ropes	60-70 mm in 18 months	(Bøhle & Wiborg, 1967)
Zuiderzee (Holland)	Bed	72 mm in 3 years	(Quoted by Andreu, 1958)
Wash (England)	Bed	54 mm in 3 years	
Aiguillon (France)	Bouchot	40 mm in 2 years	
Conway (Wales)	Bed	61 mm in 5 years	

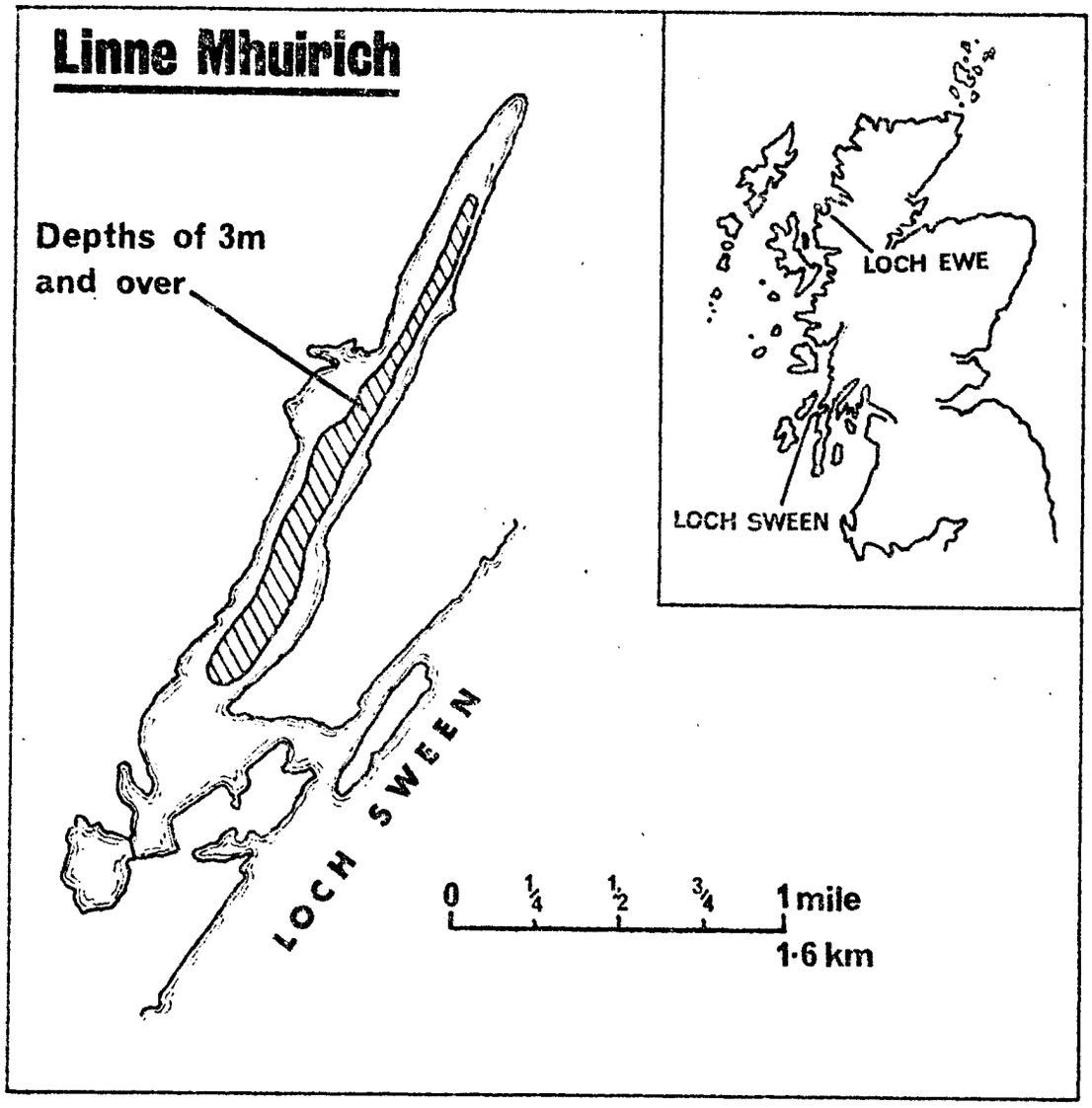

FIG. 1. Map showing sites of experiments

Fig. 2. Growth of Spring Settlement 1966 and 1967

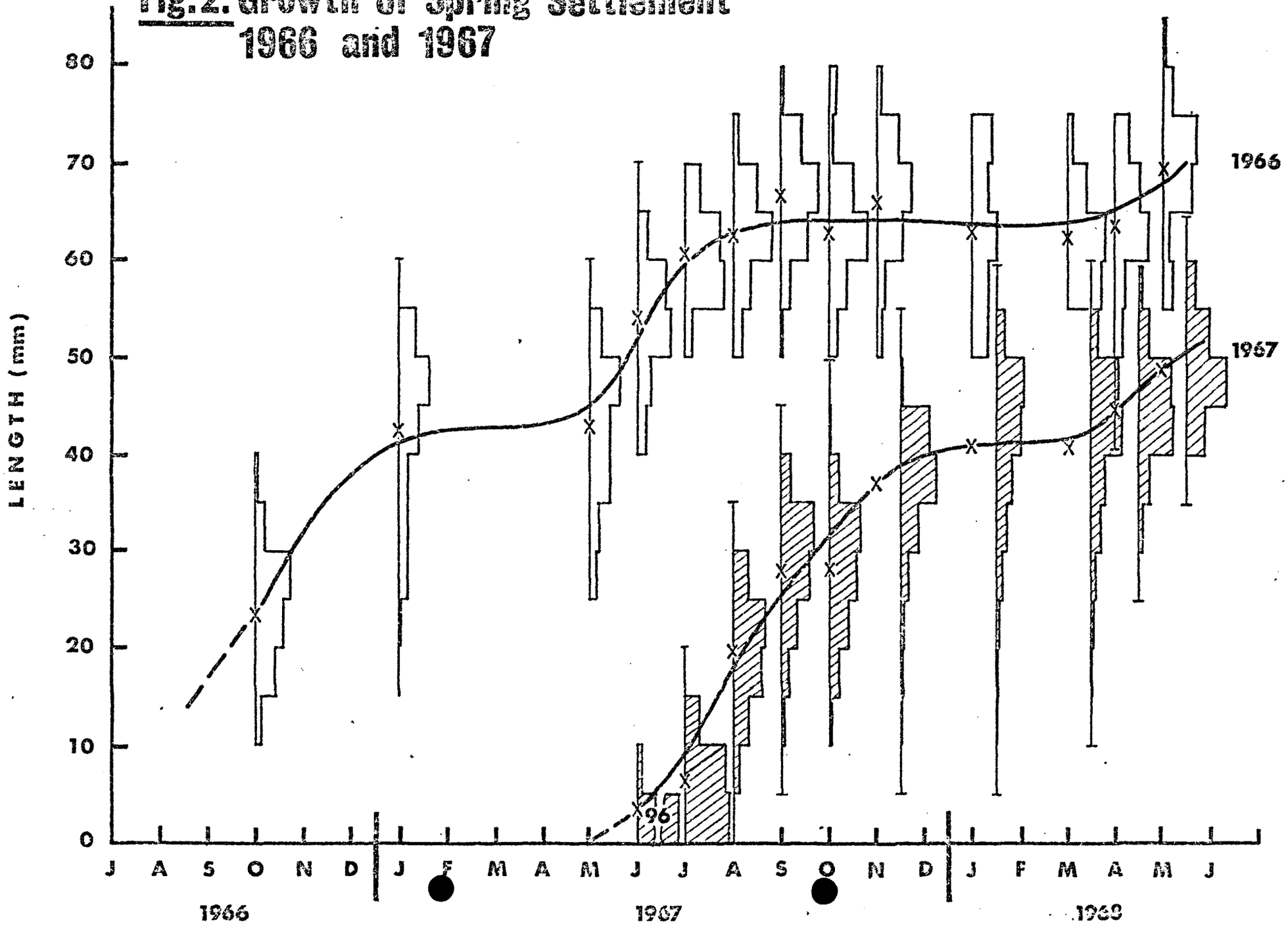

Fig. 3. Condition Factors of Spring 1966 settlement