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Experiments with cultivation of mussels in Norway

by

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INTRODUCTION

The mussel (Mytilus edulis L.) is found along the Norwegian Coast from the Oslo Fjord to Kirkenes in Northern Norway in variable densities on nearly all kinds of substrata (Wiborg og Bøhle 1968). In sheltered areas with moderate pollution, density of mussels may be very high. Northwards from Bergen mussel beds become more and more scarce and the dense populations are often found on wooden piers. The density of mussels may be high on some beds in Southern Norway, but in most areas the extension of these beds and the number of mussels are too small for commercial exploitation. The beds are frequently found on rocky shores which are too steep and rough for dredging, and in some localities the water is too shallow to permit commercial fishing vessels to operate.

Experiments with cultivation of mussels were performed more than 60 years ago (Bjerkan 1910) when spat collectors of birch twigs were suspended from buoys. The spat was transplanted to wire baskets for further growth. At the Biological Station, Arendal, some cultivation experiments have been performed since 1943 (Løversen 1957). The intention was to develop a simple and inexpensive method to provide fishermen with mussels for bait.

Spat collectors made of galvanized iron wire were suspended from thick wires over narrow bays and sounds. Collectors were also suspended from chains between buoys. In these experiments the mussels remained untouched on the collectors until they were harvested. After 1½ year the mussels attained a length of 45-60 mm, after 2½ year 70-80 mm.

The main spawning of mussels in Norway occur in April-May when sea temperatures are 8-10°C (Bøhle 1965). In the Oslo Fjord the settlement of larvae usually starts in the first days of June. The peak of settlement occurs in mid June and the settlement is finished at the end of the month. On the West Coast, the spawning and settlement seems to occur about one week earlier than in the Oslo Fjord, possibly because of higher sea temperature during winter (Bøhle, unpublished data). Minor settlements of mussel larvae have been observed in October by Løversen (1957) near Arendal and by Bøhle (unpublished data) at Drøbak.

In 1966 the Institute of Marine Research, started new series of cultivation experiments. The intention was to cultivate mussels for human consumption in different localities along the coast. Results from some of these experiments are presented in this paper.

HYDROGRAPHIC CONDITIONS

Along the Norwegian coast and in the fjords the sea surface temperatures varies considerably, from 16-21°C in summer to 0-5°C in winter, depending on wind and air temperature. On the West Coast sea surface temperature in winter is usually 2-4° higher than in the Oslo Fjord. Summer surface salinity usually is 20-25 ‰ or even lower after heavy rainfall. During winter surface salinity may increase to 30 ‰ or more. At Melsomvik, Strengereid, and Langenes the sea usually is covered with ice for several months in winter. In the Oslo Fjord, Melsomvik, Dalavågen, and Nordåsvatnet the sea is covered occasionally. At Kvitsøy and Tertnes ice cover is rare.

EXPERIMENTAL PROCEDURE

Spat collectors were suspended from rafts (7.5 x 5 m), with floats made from foam plastic. Each raft has a buoyancy of approximately 2 tons, which is sufficient to carry 8 tons of submersed mussels. In 1966, 1967, and 1968 eight rafts were anchored at different localities in Norway (Fig. 1).

As spat collectors were used galvanized iron wire (diameter 3 mm), synthetic fibre ropes (circumference 7/8 - 1½ inches), sisal ropes (1 inch), and sisal ropes tarred with coal tar. The spat collector usually were 2-4 m long, but longer collectors has also been tried. The collectors were suspended ca. 0.5 m apart, Mussels were left on the collectors without thinning until they were harvested.

Samples for determination of length distribution and length increase were taken directly from the ropes and wires. Because the clusters slided down the collectors (particularly at Snarøya and Drøbak), it was difficult to find representative samples of mussels in the late autumn of the second year.

RESULTS

Settlement

In the Oslo Fjord heavy settlement of mussel larvae has been observed. At Snarøya 60,000 spat were recorded per meter of synthetic fibre rope (7/8 inch). At Kvitsøy and Dalavågen (on the outer coast) settlement was light with only a few spat in the upper meter below surface, probably due to shortage of larvae and stratification of the water masses or too late submersion of the spat collectors. The settlement recorded on the South-east Coast (Strengereid and Langenes) was satisfactory while at Tertnes and Nordåsvatnet near Bergen, the settlement was heavy.

On the anchor chains at Drøbak, the mussel larvae settled at all depths, from surface to close to the bottom (10 m), with the highest number of spat at 1-1,5 m below surface. At Nordåsvatnet, spat was not recorded in the upper half meter, whereas at Dalavågen and Kvitsøy the spat settled in the upper meter only. Although the hydrographic data from the experimental period are not detailed, it is reasonable to assume that the top layer in Nordåsvatnet is too brackish (in rainy periods below 15 ‰ S) for settlement. In contrast to this the surface layer is probably the only water mass where the salinity is sufficiently low to be accepted by the larvae and spat in the outer areas at Dalavågen and Kvitsøy. Another explanation may be that the mussel larvae do not occur in the water masses below one meter depth in the outer areas.

The importance of filamentous algae for the settlement of spat was first pointed out by de Blok and Geelen (1958). Bayne (1964) stressed that after "primary settlement" the larvae detached the algae.

In our experiments it has been found that iron wire must be submerged some time before the expected settlement to obtain good fouling by filamentous algae to which the larvae may attach. In fact, the filamentous algae act as a fishing net (Fig. 2). In July and August when algae loosen and decay, a sufficient number of spat has moved to the wire and attached permanently there. Figure 2 also show formation of clusters with small mussels inside and large ones in the outer parts. The Figure also show an effect of sliding of clusters.

If hairy ropes are used, the spatfall is more or less independent of algal fouling. In areas where the number of mussel larvae in the water is high (i.e. the Oslo Fjord and Nordåsvatnet), it may even be an advantage to submerge ropes late too reduce algal fouling and so the number of larvae.

It is assumed that hairy ropes of synthetic fibres (or tarred sisal) will be the most convenient spat collector on most localities in Norway. Iron wire is less expensive but can only be used once and is more troublesome to handle. Because the number of spat in the sea and the fouling by filamentous algae vary considerably between different localities along the coast, choice of spat collectors and time of submersion must be based on local experiences.

In areas suitable for mussel cultivation the main settlement problem are caused by too high densities of spat, and further experiments are made to develop a simple thinning method and to find a collector which allows only a small portion of the mature larvae to settle.

Growth

Data from Snarøya, Melsomvik and Langenes are not reported here. After settlement in June, the length increase was high (Fig. 3). In September the mussels attained a mean length of 15-20 mm (maximum of individual mussels 25-30 mm). In December mean lengths of 25-30 mm were recorded with individual maxima up to 45 mm. At Dalavågen the growth was more slow. At Kvitsøy the mean length of mussels was 40.4 mm in August 1967. This is a fairly high value. However, the number of mussels on the wires was negligible due to very slight settlement the previous year.

In winter when the surface temperature usually is 0-5°C, the growth is reduced. In August-September during the second year, the mussels attained mean lengths of 45-55 mm (maxima of individuals 65-75 mm) at localities with the highest length increase (Snarøya, Drøbak, Strengereid, Nordåsvatnet, and Tertnes).

Production

Due to high growth rates, mussels grown on ropes and wires in Norwegian waters have very smooth and thin shells which constitute only 29 % of total body weight.

As a measure of quality of mussels is used the term condition index which is

$$\frac{P_{\text{steamed meat}}}{P_{\text{hole mussel}}} \cdot 100$$

The condition index varies considerably between different localities and with the time of the year. The highest values (usually about 30) are obtained in autumn and winter. However, extremely high values have been recorded in August (40.8). After spawning in April-May, content of mussel meat is very low and index values below 20 are common. In the Oslo Fjord the highest values have been recorded in March-April before the spawning.

It is assumed that minimum length for marketable mussels in Norway may be set to 50 mm for mussels of high quality (condition index 25-30). The mussels then may be harvested the second autumn, 14-18 months after settlement, depending on growth and condition index.

Table 1 show that a sample of mussels which contains a high per cent by number (50.6) of small mussels also may have a fairly high per cent (67.4) by weight of mussels $\geqq$ 50 mm.

Results from three localities which have been classified as suitable for mussel cultivation are compared in Table 2. Maximum weight of mussels obtained per meter wire was 19.6 kg but the record from Strengereid was only 9.5 kg. The number of mussels was moderate (785) at Strengereid but high ($>$ 1,900) at Nordåsvatnet and Tertnes. The per cent by weight of mussels $\geqq$ 50 mm is highest at Strengereid (76), probably because of less crowding.

However, the weight of mussels $\geqq$ 50 mm per meter collector is higher at Nordåsvatnet and Tertnes (10.6 and 13.1 kg respectively) than at Strengereid (7.2 kg) and the production given as weight of mussels $\geqq$ 50 mm is nearly twice as high as at Tertnes, even with 2 months shorter growth period. The production given as steamed meat from mussels $\geqq$ 50 mm per meter collector at Tertnes (5.37 kg) was nearly 3 times as high as the value at Strengereid (1.85 kg). However, yields of steamed mussel meat is expected usually to be 2-3 kg per meter collector.

To avoid overcrowding and sliding of clusters during the growth, and for practical reasons when harvesting the mussels, the final weight of mussels per meter collector ought to be not more than ca. 12 kg. From our observations and calculations it seems that 1,000 spat per meter collector will give ca. 12 kg mussels in 14-18 months.

Starfish predation

In 1967, starfish larvae settled on the lower parts of spat collectors (2.7-3.0 m below surface) in Nordåsvatnet. In 1968, even if ropes and wires did not touch the bottom, settlement of starfish occurred on the spat collectors at all depths in all localities, both in the Oslo Fjord and in the Bergen area. The starfish (*Asterias* spp.) found very good conditions among the mussel spat. At Nordåsvatnet, except in the upper half meter, nearly all the spat was eaten in 3-4 months. On the localities in the Oslo Fjord, the number of starfish were lower and predation lighter. It is supposed that unusually high salinity in the surface layer has favoured the starfish in 1968.

SUMMARY

In cultivation experiments from rafts, settlement of spat varied considerably and up to 60,000 spat per meter collecting ropes has been recorded. On most localities the growth rate was fairly high, usually a mean length of 30-35 mm was attained after six months growth. In some localities the mussels may be harvested after 14-18 months from settlement, at a mean length of 45-55 mm. After a growth period of 14 months, up to 19.6 kg of mussels per meter wire has been recorded, of which 13.1 kg were of marketable size ($\geqq$ 50 mm). In most localities the yield of steamed mussel meat may be expected to be 2.5-3.0 kg per meter collector.

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Table 1. Length and weight distribution of mussels on collector at Tertnes 11. August 1967

Length group	Number	%	Weight g	%
30 mm	21	11.2	55	2.8
35 "	14	7.5	60	3.0
40 "	31	16.5	190	9.6
45 "	29	15.4	245	12.4
50 "	40	21.3	450	22.7
55 "	29	15.4	440	22.2
60 "	20	10.6	360	18.2
65 "	4	4.1	85	4.3
Empty shells etc.			90	4.6
	188	100.0	1975	100.0

Table 2. Production of mussels on ropes and wires

	Strengereid	Nordåsvatnet	Tertnes
Date of sampling	17. Okt. 1967	7. Sept. 1968	11. Aug. 1968
Months from settlement to sampling	16	15	14
Weight (kg) per meter collector	9.5	15.6	19.6
Number of mussels per meter collector (calculated)	785	1925	1955
Weight % P_{50}	76	69	67
Weight (kg) of mussels $\geq$ 50 mm per meter collector	7.2	10.6	13.1
Condition index	25.5	24.6	40.8
Steamed meat per meter collector (kg)	1.85	2.61	5.37

Fig. 1. Localities where cultivation experiments have been carried out.

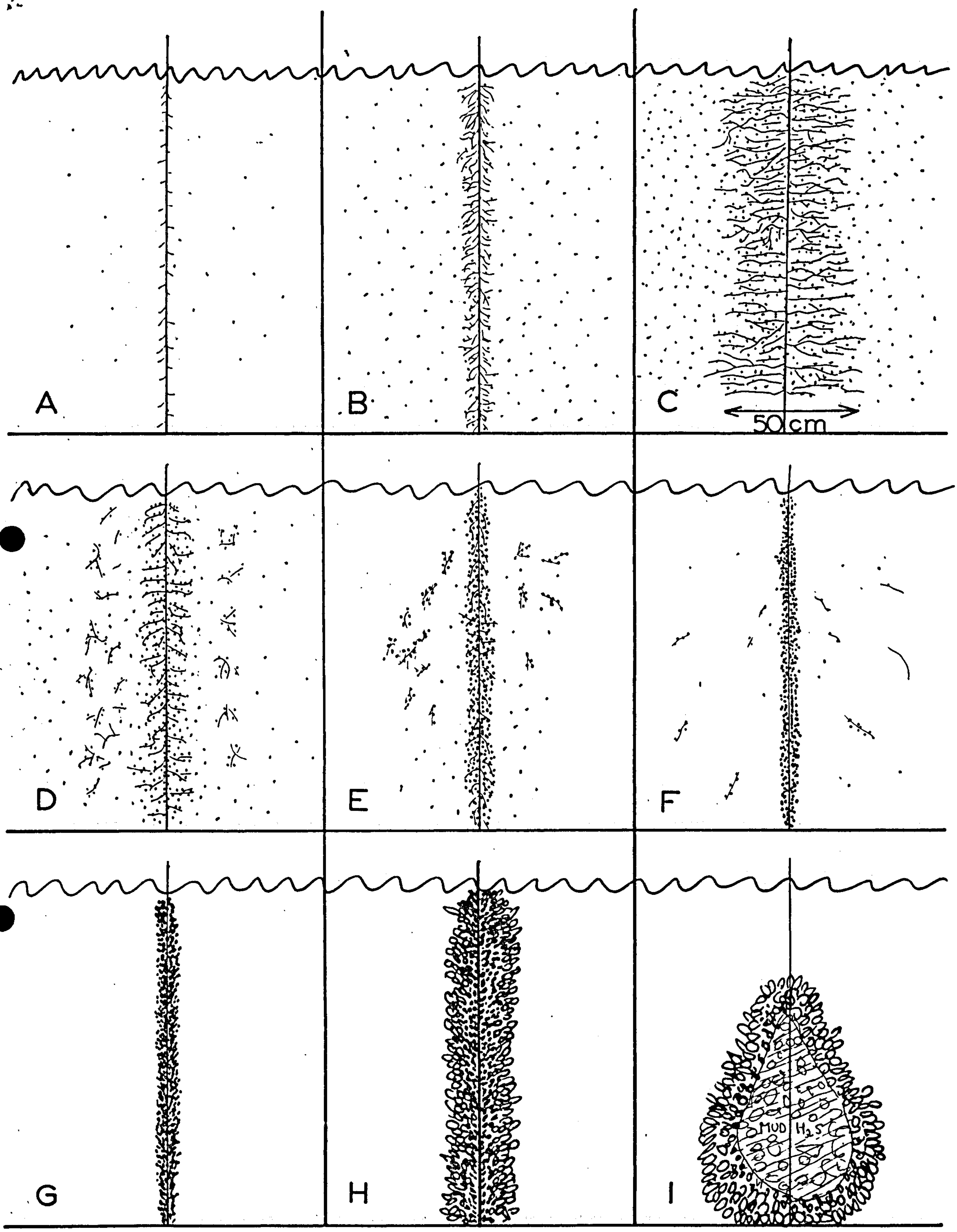

Fig. 2. Settlement of mussel larvae on spat collectors with filamentous algae and formation of clusters of mussels (explanation in the text).

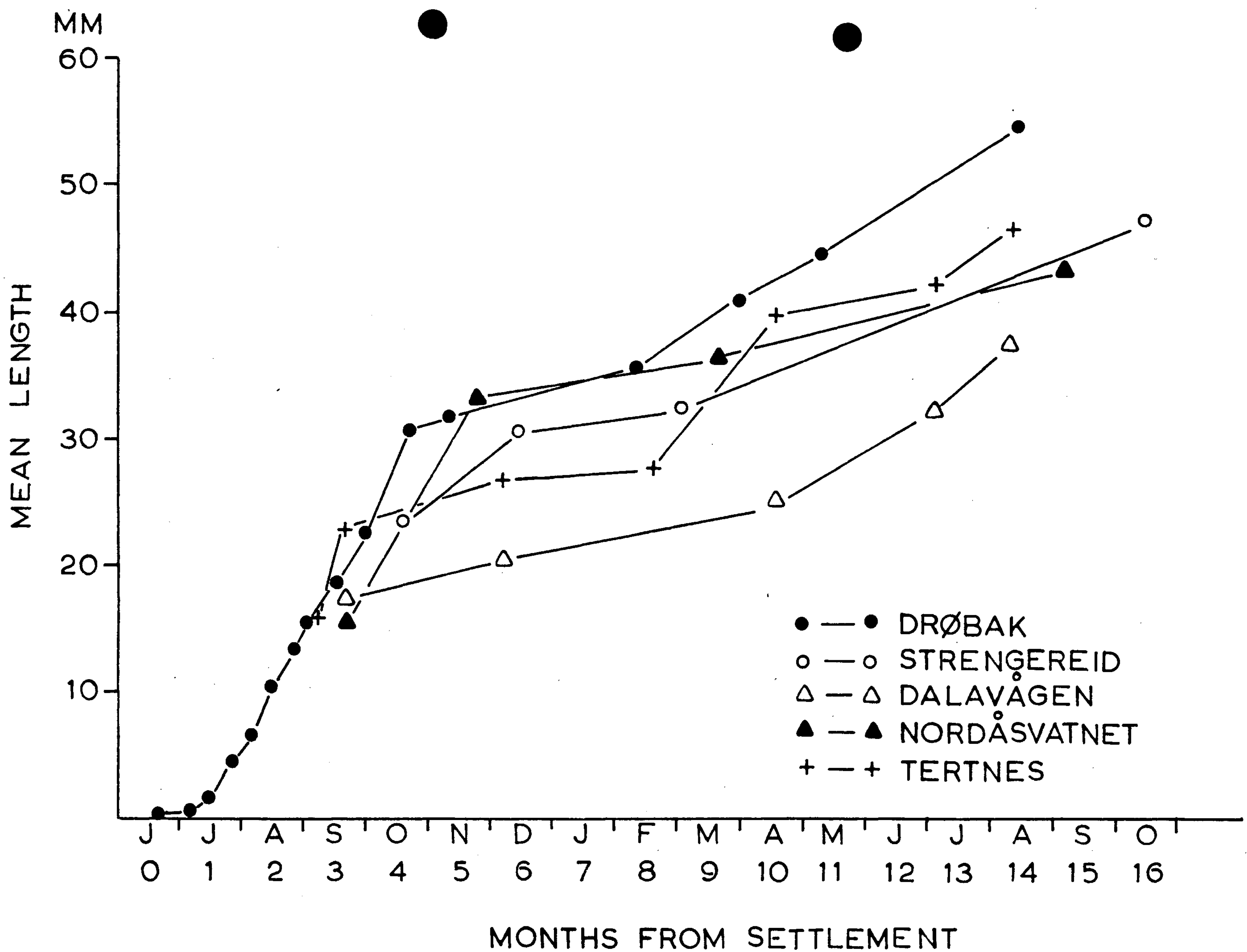

Fig. 3. Growth of mussels on ropes and wires