Measurements on the influence of the length of the daily submergence time on the condition and appearance of mussels (*Mytilus edulis* L.)

by

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Contents

I. Summary

Mussels (*Mytilus edulis* L.) living at different intertidal levels (viz. about 40, 10, and 0% of time exposed to the air) were compared as to length distribution, meat and shell weight, and lineair dimensions.

The long-exposed mussels were found to be in average smaller, to contain less meat, to have heavier shells and a more blunt shape tha the lower-living ones.

The mussels were found to grow allometrically: their width increases faster than their height, especially at the higher intertidal level.

II. Introduction

This work was carried out from the end of July 1971 till the beginning of October 1971 at the N.I.O.Z. - Texel. In the harbour of N.I.O.Z. mussels can be found between the stones of the dikes as these are a suitable substratum for the mussels to be fixed. They also can be found abundantly in the neighbourhood on the sandy flat, where they form banks.

At the dike there, we can easily see that mussels are living in different levels. Consequently, they differ in daily submergence time. The same occurs on the mussel banks. The aim of the investigation to be described in this paper, was to study how mussels may be affected by the tidal level at which they live.

Originally, I intended to work as follows: to take young mussels from cultures, or from any place where good conditions are prevailing, and to choose from them individuals of the same length (therefore, they would be of about the same age) and to place them all in one area but at different tidal levels inside nets hanged to posts driven into the sand in the intertidal zone near the harbour of the NIOZ. The mussels would then grow at different levels, thus during different daily submergence times. After an adequate growth we can easily observe whether there are marked effects of tidal level on growth, condition and appearance of those mussels.

It soon became clear that this program would cost too much time in view of the short period of my planned staying at the NIOZ.

Therefore I decided to collect mussels as they are in nature and from different levels, to see how they vary in their condition and appearance, using for that variability different measures of lineair and weight dimensions.

Although only a small area was considered in detail, it was hoped that the results might throw some light on this influence as a whole. I think also it would be interesting to continue this investigation later on, by using more samples from different localities and I hope that this will be done.

Finally, I am very much indebted to the NIOZ people for offering all kind of help. I am particularly grateful to Dr. J.J. Beukema for his supervision of my work and his revision of this manuscript.

III. Materials and Methods

I had mentioned, that I finally intended to collect mussels as they are in nature, from different levels. First of all I was looking for the optimal point that might be suitable to collect my samples. It seemed clear to me that there are two places which might act as optimal points:

1. Mussel banks: Where it is possible to collect two samples: the first is from the lowest point of the bank. The second is from the highest point of the bank. Of course there will be a difference between the daily submergence period in water, of each of them.

2. Dike: Where mussels can be found at different levels, because the dike gradually slopes off towards the water.

As it was easier for me both to collect mussels from the dike, and to measure the levels of my sampling points there, I intended to use the dike as a place for sampling (the dike that bordered the mussel station arrangements from the north. The sampling point was from its side which slopes off towards the harbour).

I have chosen two points from the dike: the first - B - was from the highest level of the dike where I could find mussels in sufficient amounts to gather them. The second - C - was from a low level of the dike. It had, therefore, a longer daily submergence period than the level - B -. The distance between B and C was about four meters along the slope. B and C were at the same straight line, as from the water up to the top of the dike, but only differed in the level.

I thought, it would be interesting to initiate the work with the sample - A -, that was from the floating raft in the harbour where mussels can be found in very large amounts. This sample was considered by me to be a standard sample, because mussels there are submerged in water 24 hours a day, as the floating raft is constantly moving upwards and downwards during the flood and ebb, resulting in permanent submergence in water for mussels which are living there.

The sequence of samples relative to the sampling time was therefore: A, then B, and at last C. The way of sampling anywhere was of course without any selection.

In the first sample - A - on 27-7-71 from the floating raft in the harbour, it was very easy to sample because the mussels as outlined above can be found abundantly, forming clusters, sitting closely together, without any intermediate spaces. By taking 3-5 clusters I had gathered enough to obtain approximately 200 individuals of mussels.

The second sample (B) was taken on 10-8-71 from the dike. The mussels were collected from an area of about 1 m^2. They were scattered and no clusters could be found. The level was determined here as follows:

First of all the place was marked carefully, and later on, on 20-8-71, when it was beautiful weather, calm sea, and no wind (as the level measurement had to be made in such conditions), I was waiting till the incoming tide was at the meanpoint (marked point), and then it was possible to read the scale in the NIOZ harbour by somebody else. The level of B was found to be 15 cm beneath NAP (-15 NAP).

As regards to the daily submergence period in water to the level outlined above, the diagram of the <u>mean</u> high and low water during the year 1971 - Den Helder - was used. By calculation, the mean of the daily submergence period was found to be about 9.5 hours per day.

While calculating the mean of the daily submergence period by the mentioned way, it soon appeared that a complete picture could not be arrived at, in the time of my disposal, for several reasons: The wind has a great influence on the strength of the current, the time of covering, and even on the direction of the current. As I know that the mean of the low and high water is calculated regardless of the wind and its influence on the tide, it should be understood, however, that the method I used was a rough one, and only to throw some light on the subject. By the way, the level -15 NAP is higher than the highest top of mussel banks, as I have seen that the whole banks are submerged in water before the mentioned level. Mussels above this level hardly can be found, but looking for the mussels carefully I was able to find a few of them up to the level +40 NAP confined to the narrow grooves between the stones of the dike.

The third sample - C - was taken on 24-8-71 from the dike. Mussels were collected from an area of about $\frac{1}{4}$ m^2, as mussels here were found occasionally to form small clusters attached to the stones.

Because the scale in the harbour beneath the level -15 was damaged, the level at - C - was determined in the same day as follows:

By using the tide table of the low and high tide that belongs to Den Helder I knew that the second low tide is (-89) at 16.26, but as I know that the second low tide in Oudeschild (the same in the harbour) is after 35-40 minutes of that in Den Helder, it was possible for me to wait till the time 17.03, the outgoing tide in the mentioned time is approximately at the level (-89 NAP), and my third sampling point - C - was just at the level.

It must be added however, that it was difficult to determine the moment of high and low water when watching the current, as it very seldom stopped, and then started flowing in the opposite direction, but as a rule turned round gradually. Anyhow I was more dependent on the time to determine the level than watching the tide.

As regards to the calculation of the daily submergence period in water at the level -89 NAP, it seemed to be impossible to use the same method I used for the sample - B -, because the diagram of the mean high and low water during the year 1971 - Den Helder - gives the number (-87 NAP) as the mean of the lower tide during the year. Therefore, if I wanted to draw the level (-89 NAP) of the sample - C - on the diagram, the line will be beneath the level (-87 NAP) of the mean. That means the level (-89 NAP) would be submerged in water 24 hours a day, but that is not true, because the same tide table gives many times as a low tide in a day, numbers beneath (-100 NAP), consequently the level (-89 NAP) is emerged, at least for a short period of time at many days during the year.

As it was necessary to determine the daily submergence time for this level, and as the way I used for the sample - B - is impracticable here, the only thing I can do is to estimate the period, in my opinion it is in average about 22 hours a day. This is about twice the submergence time at - B -.

After every sampling I used to clean the mussels completely from the outer surface, and then to keep them in the room of zero degree C to the next day, when I began to measure the length - L -, the height - H - and the width - W -, for every mussel giving a figure to each of them. Such a work took two days. On the third day I divided the whole sample into groups of mussels of nearly the same length. Mussels in the same millimeter were joined together in one group, whereas mussels beneath the length 18 mm were joined in groups with a range of 2 mm (for instance, mussels between the length 15-16.9 mm were joined together in one group). On the same day I used to take the meat out of the shell by placing every group in boiling water for a period of about 1 minute, in order to separate the valves, and the meat then becomes available. As that takes less than 1 minute for the small mussels, I used to take them out of the boiling water just after the two valves separated. After taking the meat out of the shell, I put the meat in the drying stove (60 ^{o}C). The same I did with the empty shells. The meat was exsiccated during 4 days. The total dry meat weight for every group was taken. After burning the dry meat for 2 hours at 600^{o} degrees, the total ash weight for every group was taken. By subtracting the total ash weight for every group from the total dry meat weight of the same group, I got the total ash free dry weight for this group, and then the average per mussel of the ash free weight (in milligrams).

Being interested in the amount of flesh per unity of total volume, I determined to use a condition factor, defined as:

$$\frac{\text{the average of ash free dry weight (mg)}}{\text{average of cubic length } (\text{mm}^3)} \quad \text{or} \quad \frac{\text{ash free dry weight}}{L^3},$$

as a quality index to the groups in every sample.

Cubic length was used here instead of volume, as it was not easy to measure the real volume in any accurate way. The average of cubic length was calculated by taking the cubic of every individual length in the group, then the total cubic length divided by the number of individuals in this group. As the condition factor I got was a small number I multiplied it by 1000.

The average of length (L) for every group was calculated also, the average of dry shell weight, the average of height (H), and the average of width (W).

IV. Results

1. Length distribution.

The figures 1, 2, and 3 show the frequency distribution of the lengths of the mussels of the three samples A, B, and C, respectively. The mussels had been allotted to 1-mm groups (in a few instances 2mm-groups).

Figure 4 shows the length distribution (per 2mm-interval) of all mussels (A+B+C). There is one large peak at about 40mm, sloping down to about 30mm and to about 60mm. The mussels smaller than 30mm are very unevenly distributed over both the length classes and the samples. Moreover, the small mussels will have been young mussels and thus will have lived only a relatively short time at the level of sampling. They may be less characteristic for the sampling level than the larger ones. Therefore, it was judged better to deal separately with mussels <30 and >30mm. Table 4a summarizes the numbers of mussels and groups within the three samples. The numbers per group varied from 2 to 24, see Tables 1-3, third column. Table 4b shows the mean lengths $\pm$ 2 s.e.

The differences between the samples were caused mainly by the absence of very large (above 52mm) mussels in sample B and the relatively high numbers of very small (below 18mm) mussels in sample C.

2. The influence of the daily submergence time on the condition of the mussels.

As I mentioned before, the condition factor ashfree dry weight/$_{L}3$ was used as a quality index for the mussels. The calculated figures have been put together in the Tables 1, 2, and 3. An alternative condition factor has been calculated as ashfree dry weight/$_{L.H.W}$. The figures 5^a and 5^b show the relationships between the lengths of the mussels and these condition factor for the three samples. These graphs enable comparisons of the condition factors at the same length in the three samples.

The averages of the condition factors together with their 95%-confidence limits are shown in figure 6. The two condition factors show very nearly the same relative differences and may thus be discussed together.

Figure 6 shows that in all four cases (2 types of condition factor and 2 size classes) mussels from sample B (the highest level in the tidal zône) had the lowest condition factor. In the large mussels the four differences are statistically highly significant (both B vs A and B vs C in both definitions of the condition factor). In the small mussels the differences in condition factor between the samples are only slight and generally not significant. The difference between A and C in the large mussels is statistically significant, but relatively small. Thus only the larger mussels from the high (i.e. long-exposed) level showed a great difference in condition: they contained only about half of the amount of flesh as the mussels from low or permanently submerged levels.

Figure 5^a (and to a lesser extent also figure 5^b) show that the differences in condition factor between mussels from high and low level tend to increase with increasing size of the mussels. Especially the largest mussels from the high level (B) have very low condition factors. Probably, the larger the mussels are, the longer they had lived at the high level that is unfavorable to them. During the time the mussels are exposed to the air, they may suffer from desiccation, extreme temperature, oxygen deficit, and food deficit.

It was not expected that the average condition factor for sample A (floating raft) would be lower than that of sample C (low level, but exposed during a few hours on many days). May be, it is not necessary for mussels to be submerged during the whole 24 hours a day to reach the highest condition factor. It is also possible, however, that food conditions were worse at the floating raft, e.g. by competition. It is remembered that the mussels were very abundant at the floating raft, forming clusters.

3. The influence of the daily submergence time on the outer appearance of the mussels.

By comparing the appearance of two specimens of mussels from different levels of the dike, we can easily see, that mussels from low levels have a more smooth outer surface of the shells and that the edges of the shells are sharper. Mussels from high levels are relatively rough, full of small holes and narrow groves, and their shells are blunt.

From the Tables 5, 6, and 7 and from the graphs in figure 7 we can easily see that:

1. groups from sample B (high level) are at all lengths from about 20mm onwards broader relative to both their length and height (H/W and W/L, resp.) than groups of mussels from the other two samples. This is the quantitative expression of their more blunt appearance. Samples A (floating raft) and C (low level) are hardly different in this respect.

2. differences in the height-length ratio (H/L) are slight and non-consistent.

3. mussels grow allometrically: W/L slightly increases with length, and both H/L and H/W significantly decrease. The shape of the mussels gradually changes during their life from relatively high to relatively broad. This change is most pronounced in the mussels from the higher level (sample B).

4. The influence on the weight of the shell.

From the Tables 11, 12, and 13 and from figure 8[a, b] it is obvious that mussels from sample B (high level) have relatively heavier shells (at the same length) than those of the other two samples. Mussels from the floating raft have the lowest shell weight.

The mussels from high level (B) also had relatively broad shells (see no. 3), their height, on the other hand, was relatively low. Thus the difference in shape is probably not the (only) cause of their higher shell weight. The shells of mussels from the high level will be thicker. The function of heavy and thick shells likely is to protect these mussels from the severity of the conditions in which they live at the high and exposed (also to birds) levels.

V. General summarizing discussion

Mussels can be found at different levels from about mid-tide level to subtidally. Consequently, they differ in daily submergence time. This may especially affect their food intake, as they can feed only when submerged. A slower growth rate and a lower condition factor may be expected in mussels from high levels. The finding of the absence of very large mussels in sample B and the low condition factor of the mussels in this sample are in accordance with this expectation. Further differences between mussels from various levels were: the more blunt shape of mussels from high levels and their heavier shells at the same length. Mussels were found to grow allometrically: in the course of their life they become broader and less high, especially at high levels.

VI. Comparison with evidence from literature

The sharper appearance of subtidal mussels as opposed to the blunt mussels from intertidal places has been observed by many authors. However, so far I did not meet with quantitative data.

Better growth in length at lower intertidal levels has been found by BAIRD (1966) and SEED (1969). An increase of meat weight and a decrease of shell weight with increasing time of daily submergence has been observed by BAIRD & DRINNAN (1957) in Mytilus edulis. BAIRD (1966) confirmed the lower condition factors at high intertidal levels found by BAIRD & DRINNAN (1957). Thus, like in the present study, they found a higher ratio of shell to meat in mussels periodically exposed to the air than in permanently submerged mussels. RAO (1953), however, found the reverse, both in Mytilus edulis and in M. californianus. FOX & COE (1943), at the other hand, observed that the higher intertidal mussels had thicker shells in M. californianus, thus like in our study in M. edulis. In Modiolus demissus, LENT (1967) found no relationship between intertidal height and the ratio shell weight/ meat weight.

In conclusion: there seems to be no general relationship between tidal level and measurements of weights of shell and meat in mussels. This justifies additional studies like the one presented above.

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Table I

Mean length and mean condition factor of groups of mussels from sample A (floating raft). Condition factor = ash free dry weight of meat/L^3 in mg/mm^3 x 1000.

large mussels (>30 mm)			small mussels (<30 mm)		
mean length (mm)	mean cond./fact.	number	mean length (mm)	mean cond.fact.	number
65.6	4.6	3	28.9	6.5	12
64.2	5.5	5	27.6	5.9	5
60.8	5.4	5	26.4	7.0	4
58.6	5.7	3	25.2	5.0	5
57.1	6.4	4	24.2	5.3	9
55.7	7.8	3	22.7	5.2	2
53.4	5.2	2	19.4	5.5	8
52.6	6.5	4	15.8	6.5	2
52.3	7.1	7	14.2	5.4	6
50.4	7.6	5	12.0	6.1	5
49.8	7.7	2	9.7	6.5	2
48.4	8.1	8	8.2	7.1	6
46.8	7.3	8			
45.5	7.1	5	19.5 (20.9)	6.00	66 Total
43.9	7.6	3			
42.0	6.8	4			
40.5	8.9	3			
38.9	5.5	3			
37.6	7.2	6			
36.0	6.9	7			
34.3	5.8	3			
33.0	8.0	6			
31.6	7.1	3			
Average: 47.8	6.77	102 Total			

Table II

Mean length and mean condition factor of groups of mussels from sample B (dike, -15 cm NAP). Condition factor as in Table I.

	large mussels (> 30 mm)			small mussels (< 30 mm)		
	mean length (mm)	mean cond. fact.	number	mean length (mm)	mean cond. fact.	number
	56.7	4.2	3	28.3	4.8	3
	53.3	5.2	4	25.3	5.0	3
	51.6	2.9	7	22.3	6.3	2
	50.4	2.5	10	20.8	4.7	4
	49.4	2.9	9	19.6	4.6	2
	48.4	1.8	11	18.3	4.3	3
	47.3	3.1	14	15.8	6.1	5
	46.5	2.9	12	14.0	4.6	5
	45.4	3.0	11	8.4	5.8	2
	44.5	3.2	14			
	43.5	1.1	14	19.2 (18.9)	5.1	29
	42.5	3.4	22			
	41.3	3.5	24			
	40.4	4.3	10			
	39.5	3.3	10			
	38.4	4.1	9			
	37.5	4.4	5			
	36.6	4.3	10			
	35.5	4.5	6			
	34.4	5.2	4			
	33.5	3.6	5			
	32.5	5.7	6			
	31.2	5.3	9			
Average:	42.6	3.67	229 Total			

<u>Table III</u>

Mean length and mean condition factor of groups of mussels from sample C (dike, -89 cm NAP). Condition factor as in Table I.

large mussels (>30 mm)			small mussels (<30 mm)		
mean length (mm)	mean cond. fact.	number	mean length (mm)	mean cond. fact.	number
65.0	6.9	3	28.5	6.8	3
61.9	8.2	3	27.3	6.4	3
60.7	9.1	4	26.5	6.8	2
59.3	10.7	3	24.7	8.6	2
58.4	7.0	4	23.3	6.7	4
57.7	11.7	2	20.3	6.2	2
56.4	8.5	2	19.5	4.1	2
55.2	8.0	4	18.2	5.1	5
54.3	10.1	7	15.9	4.8	9
53.3	10.1	6	13.0	5.1	11
52.4	9.7	4	11.8	5.1	9
51.2	8.2	4	10.3	4.9	7
50.6	10.5	5	8.0	5.1	5
49.4	9.9	6			
46.7	8.5	10	19.0 (16.2)	5.8	64
45.3	8.0	7			
44.5	10.0	8			
43.5	9.2	5			
42.3	11.0	6			
41.5	8.9	9			
40.3	7.8	7			
39.5	10.2	3			
38.6	8.4	6			
37.5	11.1	4			
36.6	8.0	4			
35.0	9.0	2			
34.4	6.9	3			

Table III (continued)

Mean length and mean condition factor of groups of mussels from sample C (dike, -89 cm NAP). Condition factor as in Table I.

large mussels (> 30 mm)			small mussels (< 30 mm)		
mean length (mm)	mean cond. fact.	number	mean length (mm)	mean cond. fact.	number
33.4	8.0	4			
31.7	6.5	3			
30.2	7.5	6			
29.6	7.0	3			
Average: 46.3	8.86	147 Total			

Table IVa.

The numbers of mussels and groups within the three samples.

sample	level	number of mussels >30mm	number of mussels <30mm	number of groups >30mm	number of groups <30mm	data shown in graph	data shown in table
A	float	102	66	23	12	1,5,7,8	1,5,8,11
B	-15NAP	229	29	23	9	1,5,7,8	2,6,9,12
C	-89NAP	147	64	31	13	1,5,7,8	3,7,10,13

Table IVb.

The mean lengths $\pm$ 2 s.e.

sample	>30mm	(n)	<30mm	(n)
A	47.3 ± 1.9	(102)	20.9 ± 1.7	(66)
B	42.8 ± 0.7	(229)	18.9 ± 2.0	(29)
C	45.8 ± 1.5	(147)	16.2 ± 1.5	(64)

<u>Table V</u>

Means of length, height, and width of groups of mussels from sample A and their ratios. L = total length, H = total height, W = total width (see figure 7). All measures in mm.

large mussels (> 30 mm)						small mussels (< 30 mm)					
L	H	W	H/L	W/L	H/W	L	H	W	H/L	W/L	H/W
65.6	28.6	25.0	.436	.381	1.14	28.9	16.3	9.8	.564	.339	1.66
64.2	28.9	25.4	.450	.396	1.14	27.6	15.6	9.6	.565	.348	1.63
60.8	28.7	22.3	.472	.367	1.29	26.4	15.0	9.1	.568	.345	1.65
58.6	28.2	23.7	.481	.404	1.19	25.2	15.2	9.0	.603	.357	1.69
57.1	27.2	20.2	.476	.354	1.35	24.2	13.9	8.0	.574	.330	1.74
55.7	25.8	21.9	.463	.393	1.17	22.7	12.9	8.0	.568	.352	1.61
53.4	26.2	18.8	.491	.352	1.39	19.4	11.5	6.6	.593	.340	1.74
52.6	25.5	18.3	.485	.348	1.39	15.8	9.9	5.4	.626	.342	1.84
52.3	26.3	20.1	.503	.384	1.31	14.2	8.5	5.1	.598	.359	1.67
50.4	25.2	18.9	.500	.375	1.33	12.0	7.4	4.1	.617	.342	1.81
49.8	25.2	19.3	.506	.388	1.31	9.7	6.2	3.5	.639	.361	1.77
48.4	24.2	17.8	.500	.368	1.36	8.2	5.1	2.8	.622	.341	1.82
46.8	23.9	17.8	.511	.380	1.34						
45.5	23.6	16.3	.519	.358	1.45						
43.9	22.8	16.9	.519	.385	1.35						
42.0	20.1	14.4	.478	.343	1.40						
40.5	21.2	14.8	.523	.365	1.43						
38.9	20.0	13.1	.514	.337	1.53						
37.4	20.2	13.9	.540	.372	1.45						
36.0	19.8	12.9	.550	.358	1.53						
34.3	19.7	12.2	.574	.356	1.62						
33.0	18.0	11.2	.545	.339	1.61						

Table VI

Means of length, height and width of groups of mussels from sample B and their ratios. See Table V for abbreviations.

large mussels (>30 mm)						small mussels (<30 mm)					
L	H	W	H/L	W/L	H/W	L	H	W	H/L	W/L	H/W
56.7	28.4	24.1	.501	.425	1.18	28.3	15.5	11.0	.548	.389	1.41
53.3	26.0	22.3	.488	.418	1.17	25.3	13.7	9.8	.542	.387	1.40
51.6	24.5	22.4	.475	.434	1.09	22.3	12.5	7.9	.560	.354	1.58
50.4	23.9	20.3	.474	.403	1.18	20.8	12.1	7.3	.582	.351	1.66
49.4	24.9	20.9	.504	.423	1.19	19.6	11.1	7.0	.566	.357	1.59
48.4	23.6	19.2	.488	.397	1.23	18.3	10.4	6.6	.568	.361	1.58
47.3	23.0	19.3	.486	.408	1.19	15.8	9.4	6.0	.595	.380	1.57
46.5	23.0	19.0	.495	.409	1.21	14.0	8.5	5.0	.607	.357	1.70
45.4	22.0	17.9	.484	.394	1.23	8.4	5.3	3.1	.631	.369	1.71
44.5	21.9	17.9	.492	.402	1.22						
43.5	21.5	17.4	.494	.400	1.23						
42.5	21.6	17.3	.508	.407	1.25						
41.3	20.4	16.9	.494	.409	1.21						
40.4	20.4	15.7	.505	.389	1.30						
39.5	19.8	15.0	.501	.380	1.32						
38.4	19.6	15.6	.510	.406	1.26						
37.5	19.5	14.4	.520	.384	1.36						
36.6	18.7	14.2	.511	.388	1.32						
35.5	19.2	14.1	.541	.397	1.36						
34.4	17.8	12.9	.517	.375	1.38						
33.5	17.3	12.8	.516	.382	1.35						
32.5	17.0	12.5	.523	.385	1.36						
31.2	16.6	12.3	.532	.394	1.35						

Table VII

Means of length, height, and width of groups of mussels from sample C and their ratios. See Table V for abbreviations.

large mussels (> 30 mm)						small mussels (< 30 mm)					
L	H	W	H/L	W/L	H/W	L	H	W	H/L	W/L	H/W
65.0	31.8	27.2	.489	.418	1.17	28.5	16.4	10.3	.575	.361	1.59
61.9	31.1	24.0	.502	.388	1.30	27.3	15.0	9.2	.549	.337	1.63
60.7	31.6	23.6	.520	.389	1.34	26.5	15.7	9.9	.592	.374	1.59
59.3	29.8	22.3	.502	.376	1.34	24.7	14.6	9.1	.591	.368	1.61
58.4	28.3	22.7	.484	.389	1.25	23.3	13.4	8.1	.575	.348	1.66
57.7	27.8	23.1	.482	.400	1.20	20.3	12.1	7.2	.596	.355	1.68
56.4	29.6	21.4	.525	.379	1.38	19.5	11.1	6.8	.569	.349	1.63
55.2	26.8	21.6	.486	.391	1.24	18.2	10.8	6.4	.593	.352	1.69
54.3	27.9	21.4	.514	.394	1.30	15.9	9.5	5.7	.597	.358	1.67
53.3	27.5	20.7	.516	.388	1.33	13.0	8.5	5.1	.654	.392	1.67
52.4	27.5	21.4	.525	.408	1.29	11.8	7.1	4.2	.602	.356	1.63
51.2	27.2	21.2	.531	.414	1.28	10.3	6.2	3.8	.602	.369	1.63
50.6	27.1	19.5	.536	.385	1.39	8.0	4.9	2.8	.612	.350	1.75
49.4	25.4	19.3	.514	.391	1.32						
46.7	24.2	18.1	.518	.388	1.34						
45.3	24.0	17.4	.530	.384	1.38						
44.5	24.0	16.5	.539	.371	1.45						
43.5	22.5	15.9	.517	.366	1.41						
42.3	22.7	16.1	.537	.381	1.41						
41.5	23.0	15.0	.554	.361	1.53						
40.3	21.6	15.1	.536	.375	1.43						
39.5	20.8	15.2	.526	.385	1.49						
38.6	20.7	13.9	.536	.360	1.49						
37.5	20.9	14.2	.557	.379	1.47						

Table VII (continued)

Means of length, height, and width of groups of mussels from sample C and their ratios. See Table V for abbreviations.

large mussels (>30 mm)						small mussels (<30 mm)					
L	H	W	H/L	W/L	H/W	L	H	W	H/L	W/L	H/W
36.6	19.6	13.5	.536	.369	1.45						
35.0	18.8	12.6	.537	.360	1.49						
34.4	18.9	12.1	.549	.352	1.56						
33.4	18.6	12.4	.557	.371	1.50						
31.7	17.6	11.6	.555	.366	1.52						
30.2	17.4	10.7	.576	.354	1.63						
29.6	16.5	11.0	.557	.372	1.50						

Table VIII

Mean length and mean condition factor of groups of mussels from sample A. Condition factor = ash free dry weight of meat/L.H.W. in mg/mm^3 x 100.

large mussels (> 30 mm)		small mussels (< 30 mm)	
mean length (mm)	mean cond. fact.	mean length (mm)	mean cond. fact.
65.6	2.7	28.9	3.4
64.2	3.1	27.6	3.0
60.8	3.1	26.4	3.6
58.6	2.9	25.2	2.3
57.1	3.8	24.2	2.8
55.7	4.3	22.7	2.6
53.4	3.0	19.4	2.8
52.6	3.9	15.8	3.1
52.3	3.7	14.2	2.6
50.4	4.0	12.0	2.9
49.8	3.9	9.7	2.9
48.4	4.4	8.2	3.3
46.8	3.8		
45.5	3.8		
43.9	3.8		
42.0	4.2		
40.5	4.6		
38.9	3.2		
37.6	3.7		
36.0	3.5		
34.3	2.9		
33.0	4.3		
31.6	3.6		

Table IX

Mean length and mean condition factor of groups of mussels from sample B. Condition factor as in Table VIII.

large mussels (>30 mm)		small mussels (<30 mm)	
mean length (mm)	mean cond. fact.	mean length (mm)	mean cond. fact.
56.7	2.0	28.3	2.3
53.3	2.5	25.3	2.4
51.6	1.4	22.3	3.1
50.4	1.3	20.8	2.3
49.4	1.4	19.6	2.3
48.4	0.9	18.3	2.1
47.3	1.6	15.8	2.8
46.5	1.5	14.0	2.1
45.4	1.6	8.4	2.5
44.5	1.6		
43.5	1.4		
42.5	1.7		
41.3	1.8		
40.4	2.2		
39.5	1.7		
38.4	2.0		
37.5	2.2		
36.6	2.2		
35.5	2.1		
34.4	2.7		
33.5	1.8		
32.5	2.8		
31.2	2.6		

Table X

Mean length and mean condition factor of groups of mussels from sample C. Condition factor as in Table VIII.

large mussels (>30 mm)		small mussels (<30 mm)	
mean length (mm)	mean cond. fact.	mean length (mm)	mean cond. fact.
65.0	3.4	28.5	3.3
61.9	4.2		
60.7	4.5	27.3	3.4
61.9	4.2	26.5	3.1
59.3	5.7	24.7	4.0
58.4	3.7	23.3	3.4
57.7	6.1	20.3	3.0
56.4	4.3	19.5	2.1
55.2	4.2	18.2	2.4
54.3	5.0	15.9	2.3
53.3	5.0	13.0	2.3
52.4	4.5	11.8	2.4
51.2	3.7	10.3	2.2
50.6	5.1	8.0	2.4
49.4	4.9		
46.7	4.2		
45.3	4.0		
44.5	5.0		
43.5	4.8		
42.3	5.3		
41.5	4.4		
40.3	3.9		
39.5	5.0		
38.6	4.4		

Table X (continued)

Mean length and mean condition factor of groups of mussels from sample C. Condition factor as in Table VIII.

large mussels ($>$30 mm)		small mussels ($<$30 mm)	
mean length (mm)	mean cond. fact.	mean length (mm)	mean cond. fact.
37.5	5.2		
36.6	4.0		
35.0	4.7		
34.4	3.6		
33.4	3.9		
31.7	3.2		
30.2	3.6		
29.6	3.4		

Table XI

Mean length and mean dry weight of shells of groups of mussels from sample A.

large mussels (>30 mm)		small mussels (<30 mm)	
mean length (mm)	mean weight (gram)	mean length (mm)	mean weight (gram)
65.6	11.00	28.9	0.90
64.2	10.83	27.6	0.79
60.8	8.70	26.4	0.72
58.6	9.54	25.2	0.63
57.1	6.54	24.2	0.52
55.7	6.75	22.7	0.44
53.4	6.97	19.4	0.31
52.6	5.43	15.8	0.14
52.3	5.82	14.2	0.12
50.4	4.90	12.0	0.07
49.8	5.23	9.7	0.04
48.4	4.35	8.2	0.02
46.8	4.38		
45.5	3.43		
43.9	3.65		
42.0	3.18		
40.5	2.75		
38.9	1.86		
37.6	2.07		
36.0	1.90		
34.3	1.70		
33.0	1.38		
31.6	1.09		

Table XII

Mean length and mean dry weight of shells of groups of mussels from sample B.

large mussels (>30 mm)		small mussels (<30 mm)	
mean length (mm)	mean weight (gram)	mean length (mm)	mean weight (gram)
56.7	10.42	28.3	1.24
53.3	7.30	25.3	0.88
51.6	8.61	22.3	0.56
50.4	7.17	20.8	0.40
49.4	6.91	19.6	0.36
48.4	6.27	18.3	0.27
47.3	6.26	15.8	0.23
46.5	6.00	14.0	0.13
45.5	5.60	8.4	0.03
44.5	5.24		
43.5	4.84		
42.5	4.62		
41.3	4.30		
40.4	3.59		
39.5	3.26		
38.4	3.36		
37.5	3.06		
36.6	2.69		
35.5	2.63		
34.4	2.13		
33.5	2.09		
32.5	1.89		
31.2	1.78		

Table XIII

Mean length and mean dry weight of shells of groups of mussels from sample C.

large mussels (> 30 mm) mean length (mm)	large mussels (> 30 mm) mean weight (gram)	small mussels (< 30 mm) mean length (mm)	small mussels (< 30 mm) mean weight (gram)
65.0	13.08	28.5	1.12
61.9	10.60	27.3	0.93
60.7	11.16	26.5	0.80
59.3	9.48	24.7	0.81
58.4	9.48	23.3	0.64
57.7	9.38	23.3	0.40
56.4	9.01	19.5	0.29
55.2	7.57	18.2	0.29
54.3	7.67	15.9	0.20
53.3	7.95	13.0	0.14
52.4	7.39	11.8	0.09
51.2	7.70	10.3	0.06
50.6	6.57	8.0	0.03
49.4	5.81		
46.7	4.70		
45.3	4.69		
44.5	3.93		
43.5	3.57		
42.3	3.52		
41.5	3.47		
40.3	2.93		
39.5	2.81		
38.6	2.70		

Table XIII (continued)

Mean length and mean dry weight of shells of groups of mussels from sample C.

large mussels (> 30 mm)		small mussels (< 30 mm)	
mean length (mm)	mean weight (gram)	mean length (mm)	mean weight (gram)
37.5	2.88		
36.6	2.14		
35.0	2.08		
34.4	1.84		
33.4	1.82		
31.7	1.41		
30.2	1.20		
29.6	1.23		

Figure 1. Frequency distribution of the lengths of the mussels of sample A (floating raft

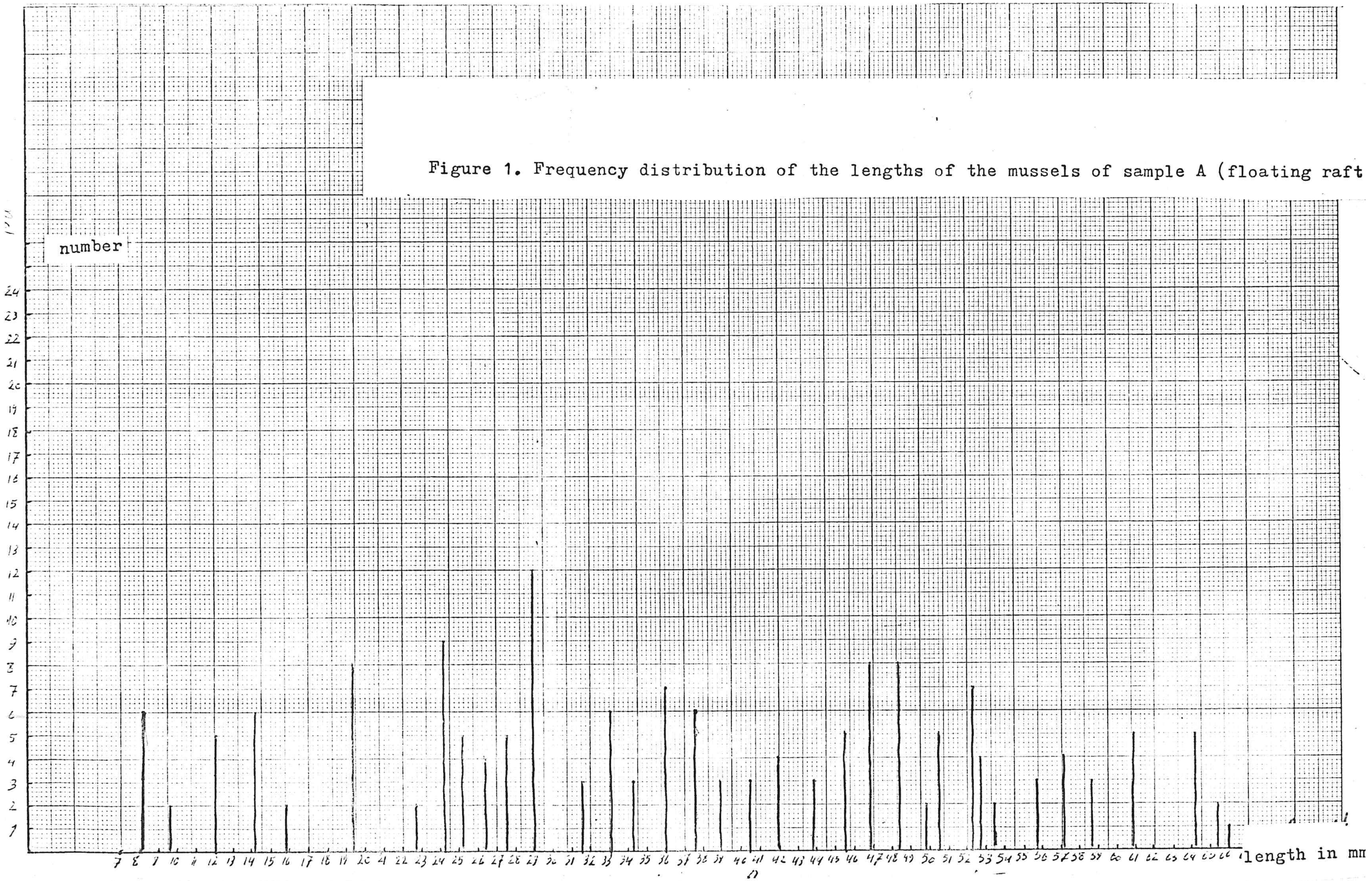


Figure 2. Frequency distribution of lengths of the mussels of sample B (-15cm NAP)

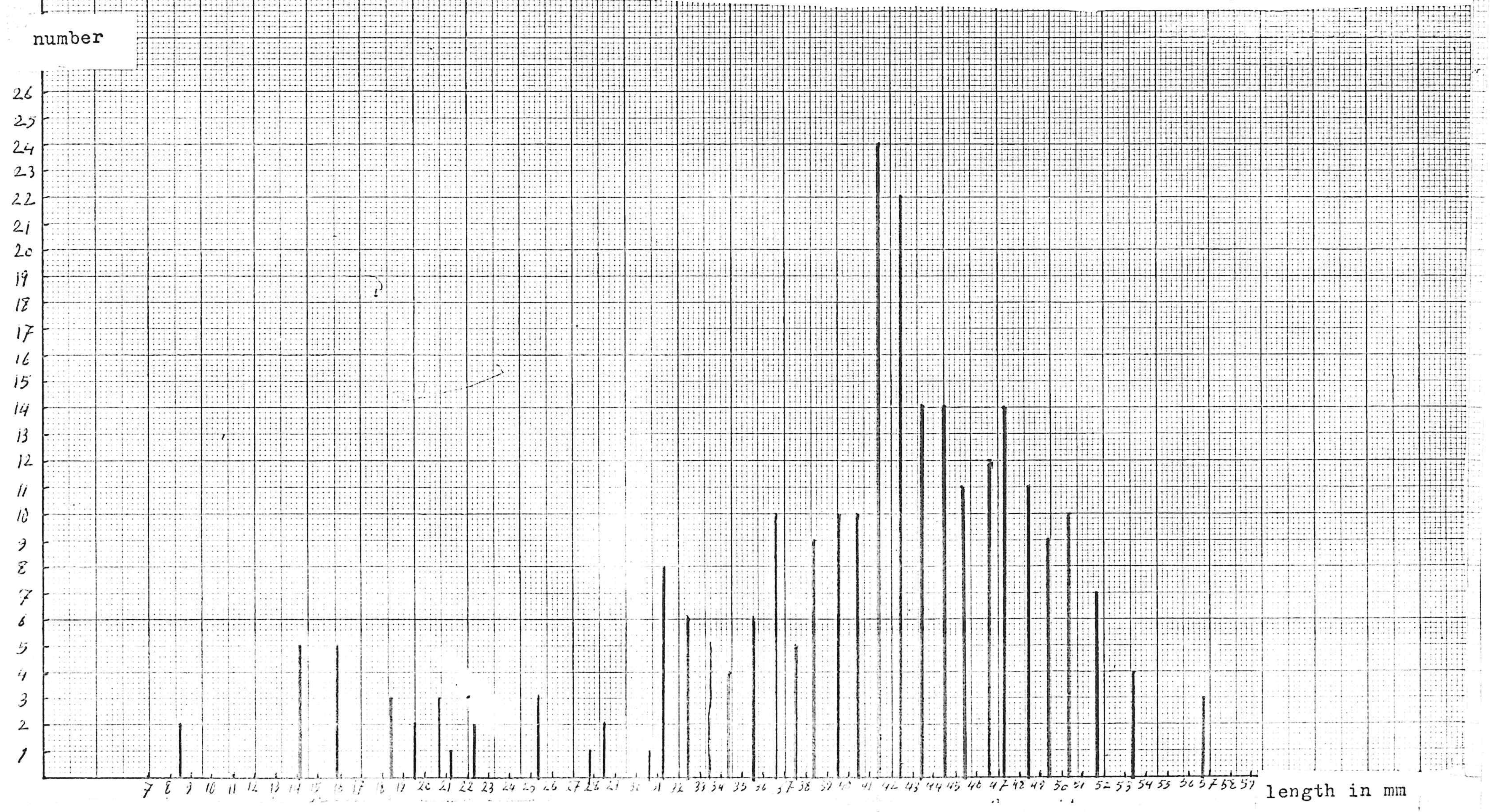


Figure 3. Frequency distribution of the lengths of the mussels of sample C (-89cm NAP)

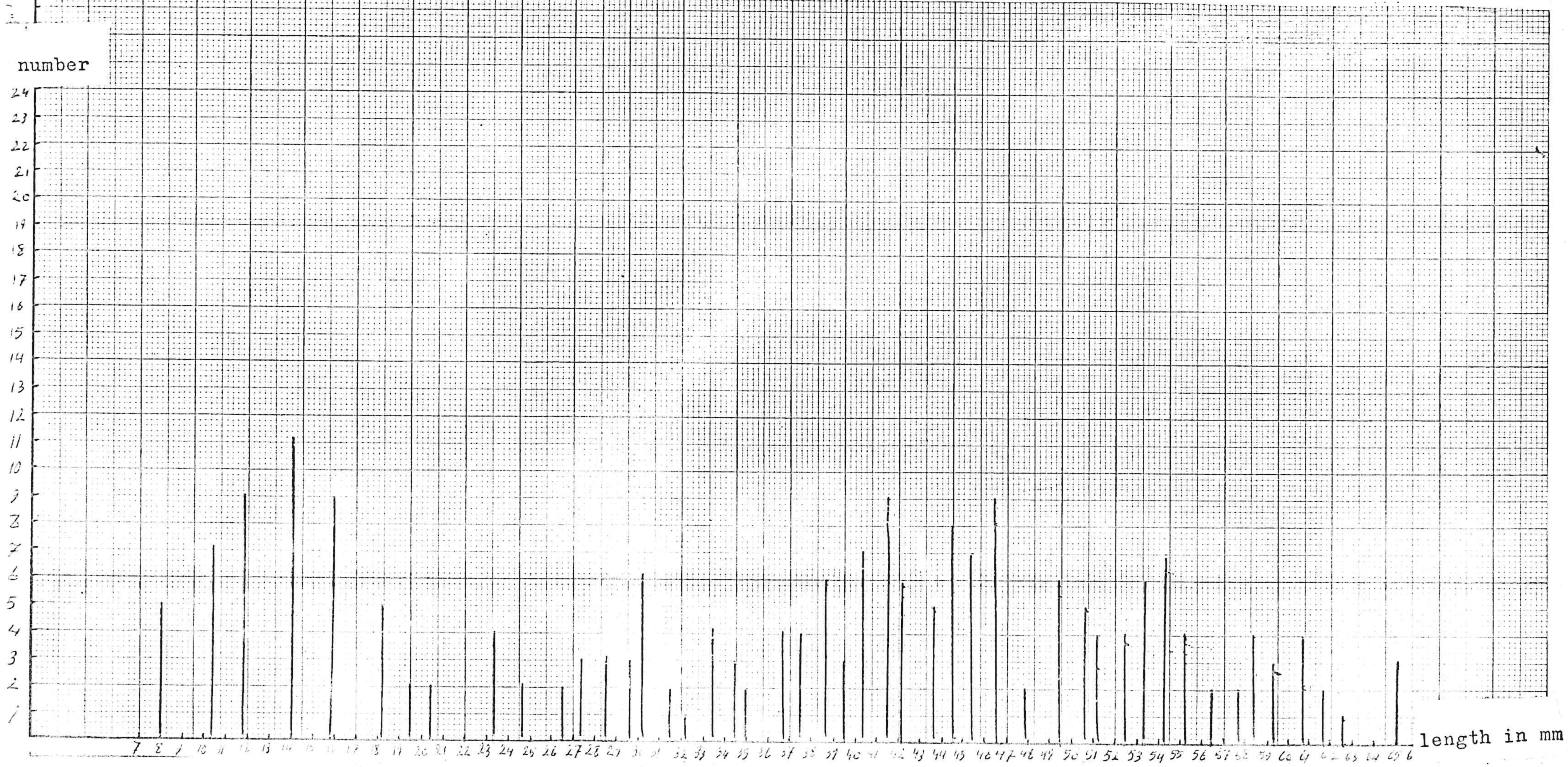


Figure 4. Frequency distribution of the lengths of all 838 mussels measured.

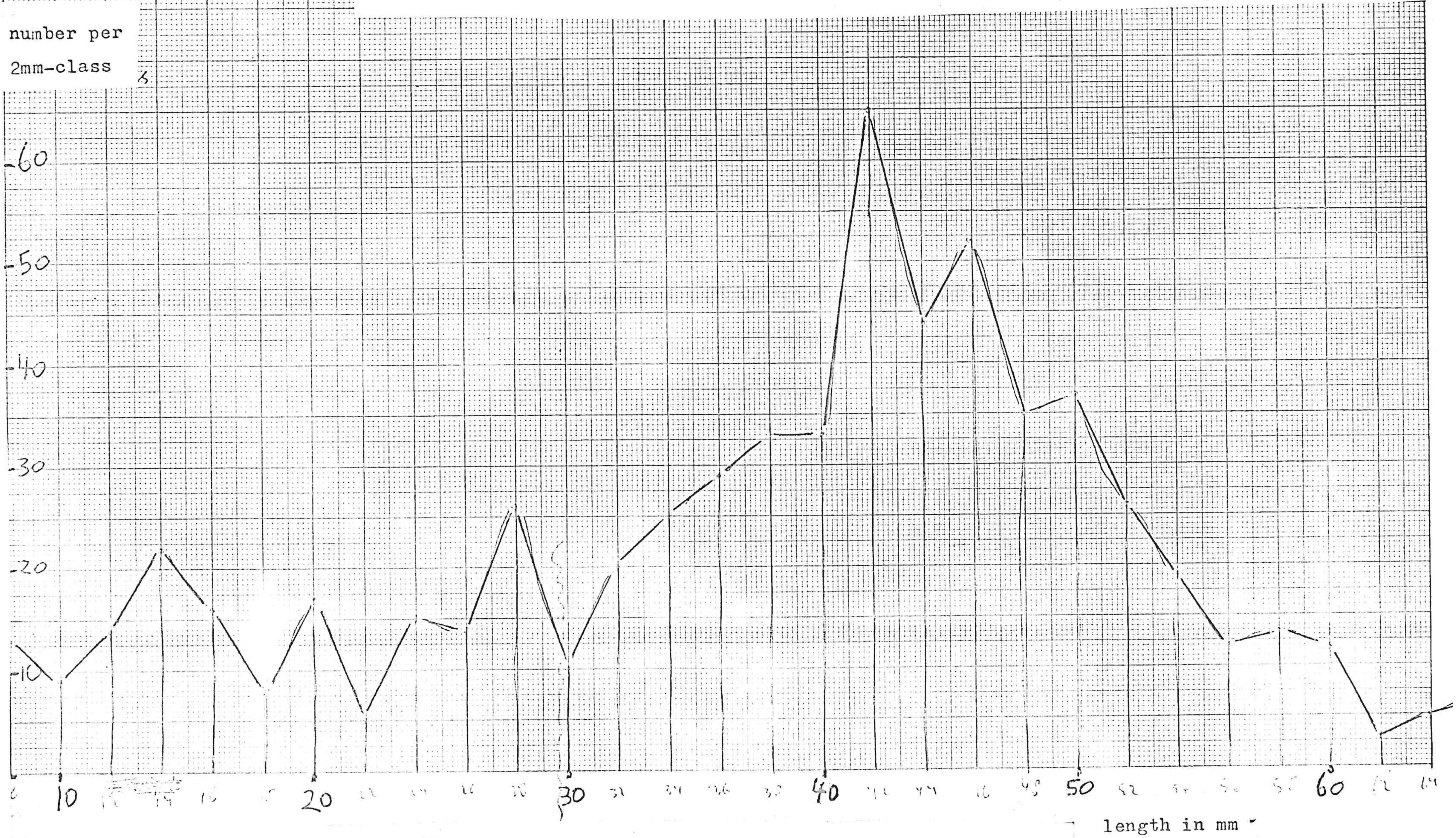


Figure 5[a]. Condition factor as a function of length for mussels from three samples:

△ A floating raft

● B −15cm NAP

X C −89cm NAP

Condition factor defined as weight/L^3

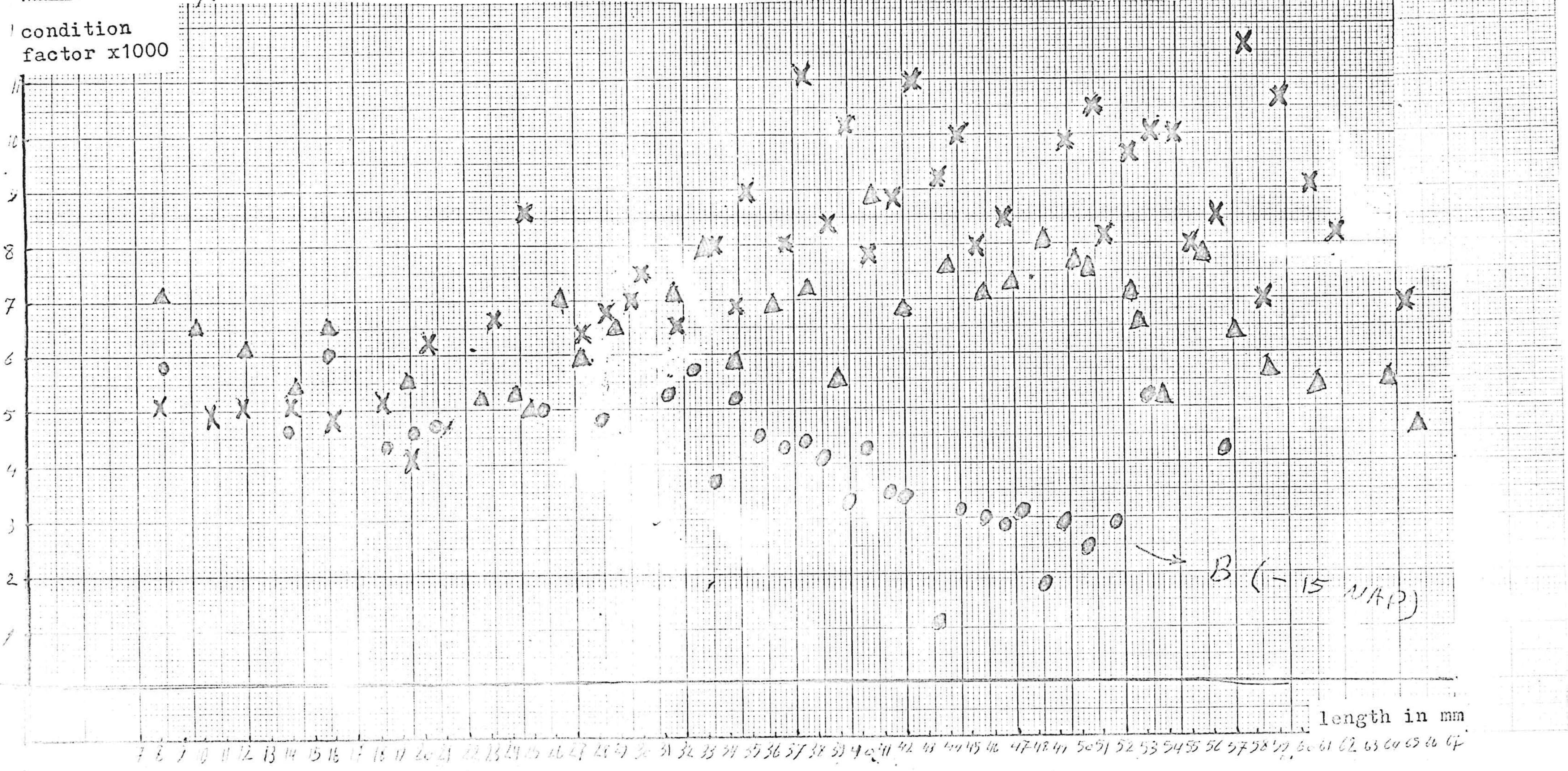


Figure 5b. Condition factor as a function of length for the mussels from three samples: A floating raft ▲ B -15cm NAP ● C -89cm NAP X

Condition factor defined as weight/ L.H.W

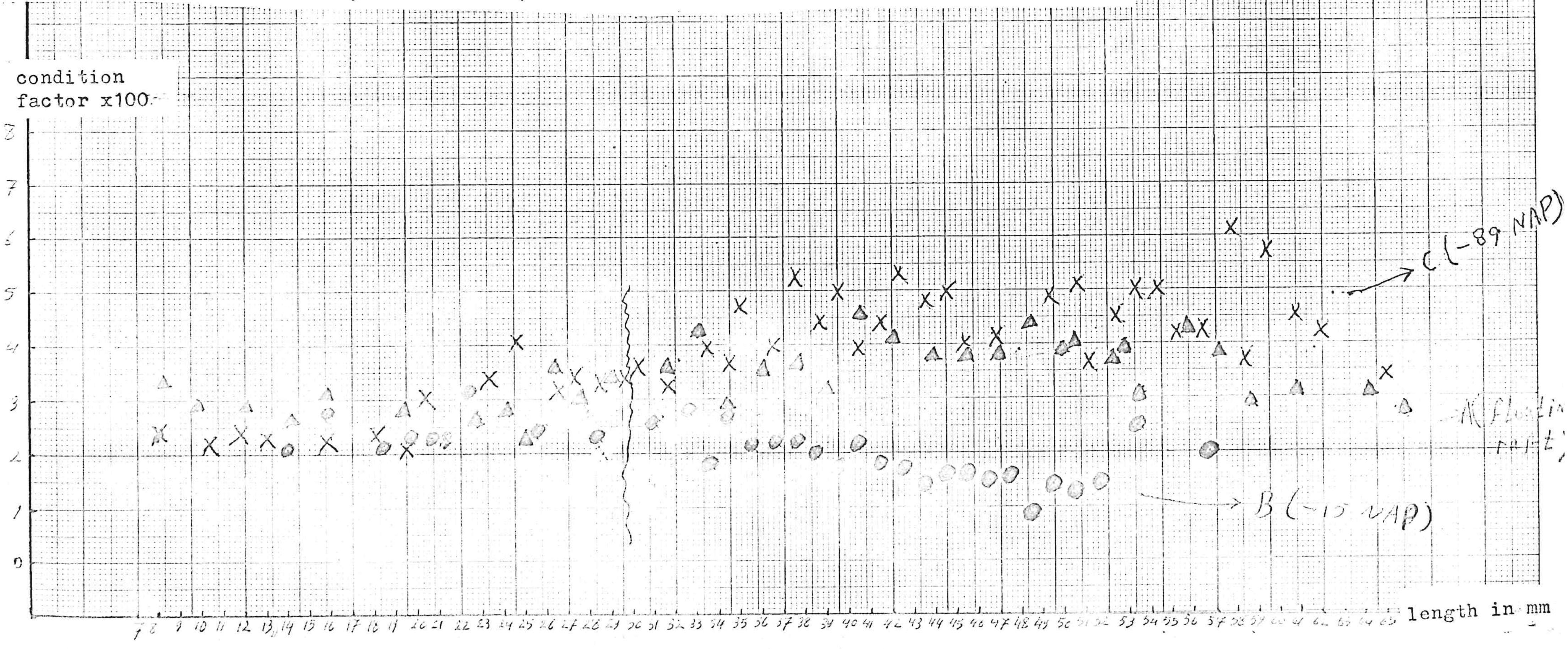
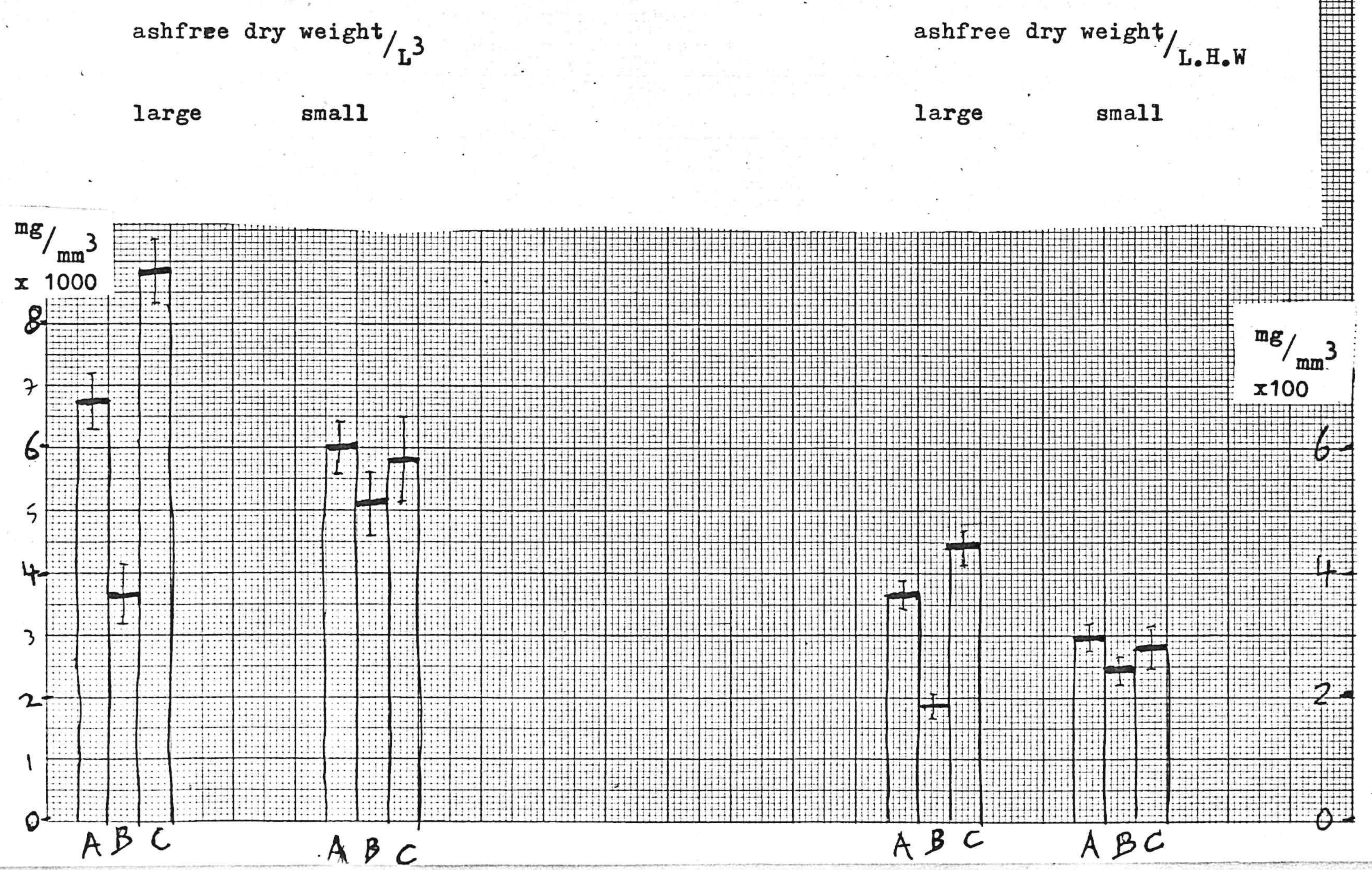


Figure 6. Mean condition factors $\pm$ 2 s.e. for large and small mussels sampled from three levels: A=floating raft
B= -15cm NAP
C= -89cm NAP



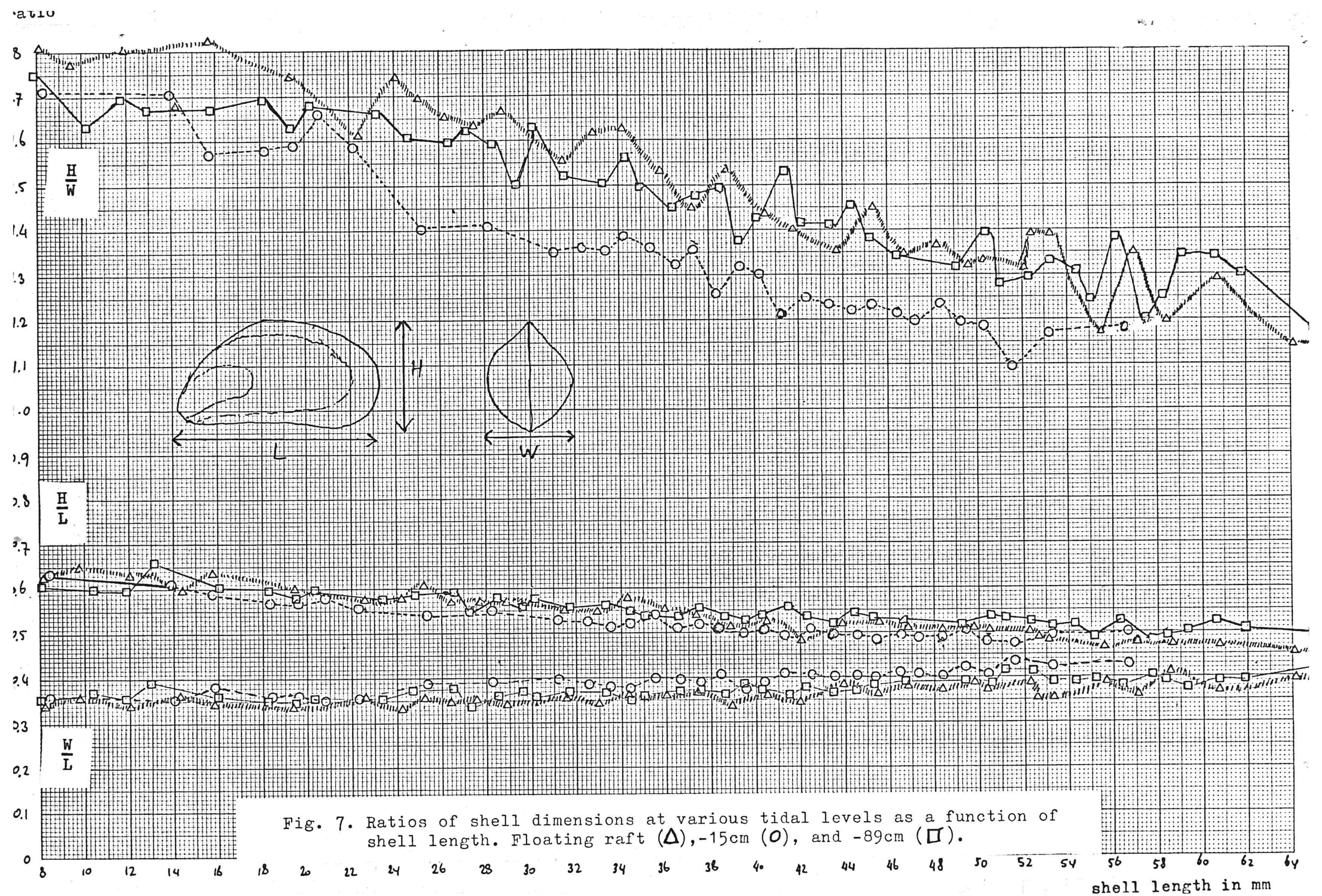


Fig. 7. Ratios of shell dimensions at various tidal levels as a function of shell length. Floating raft (Δ), -15cm (O), and -89cm (□).

Figure 8[a]. Shell weight as a function of shell length in mussels from three levels.

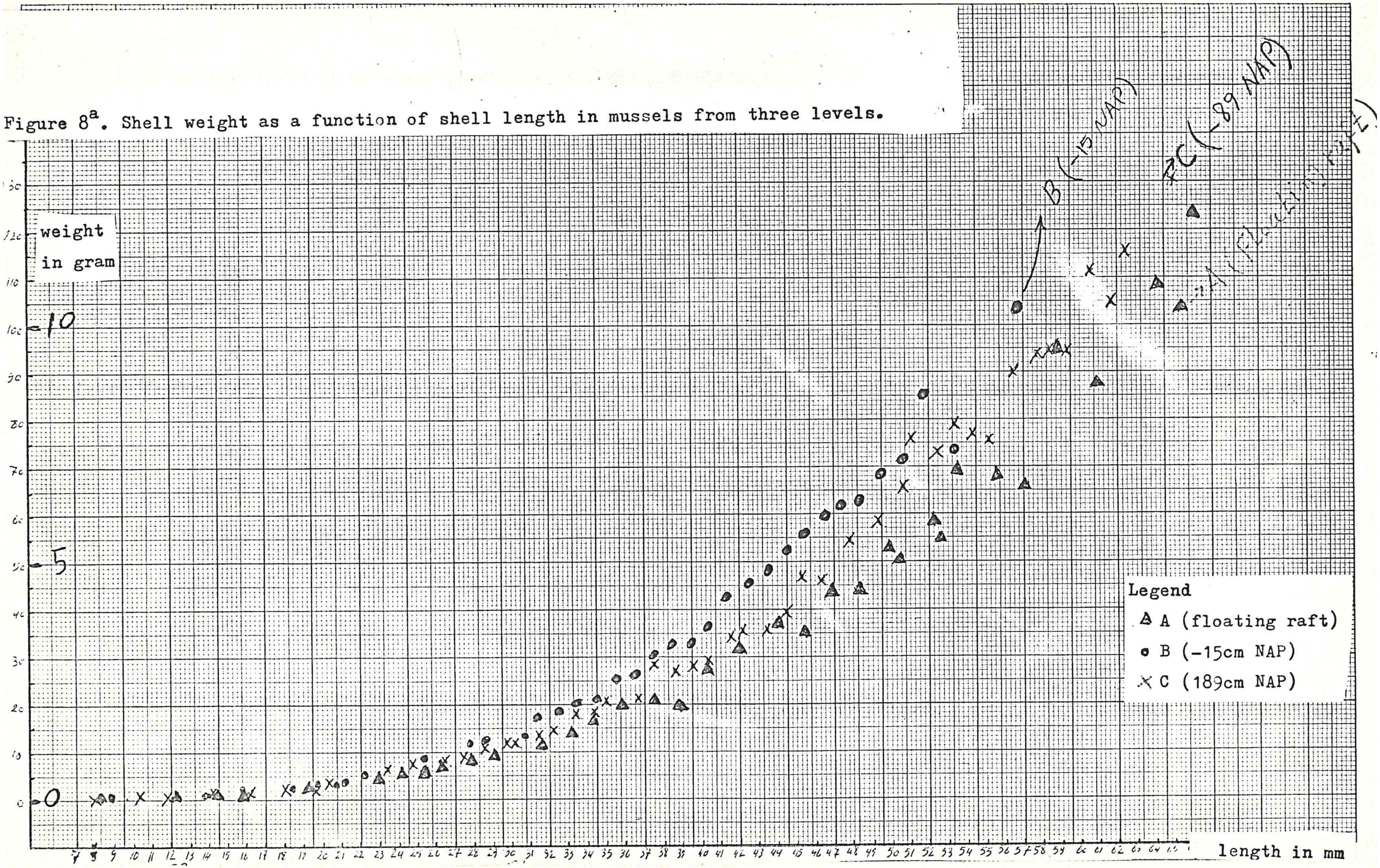


Fig. 8[b]. Logarithmic plot of shell weight as a function of shell length.

Weight of
shells in
grams