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A SURVEY OF INTERTIDAL ORGANISMS AROUND DUMPING PITS FOR POT LININGS AT STRAUMSVIK, SOUTHWESTERN ICELAND

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1. Introduction

The Institute of Biology, University of Iceland undertook to do a survey of the intertidal shore at Straumsvík, according to a contract between the Institute and Icelandic Aluminium Co. Ltd, dated 7 March 1989, in order to investigate whether any effects on the biota of the shore are discernible from pot linings from the aluminium smelter, which have been dumped in pits on the shore in and near Straumsvík. It was considered that the most effective way to do this was to do a detailed survey of the distributional patterns of local species in the neighbourhood of the dumping pits. Investigations were done at two localities. One locality is close to a pit which has been in use since 1984. The other locality is near an older dumping pit which has not been used for the disposal of pot linings since 1985. However, it has continued to be used for various refuse from the anode workshop of the smelter.

2. Methods

Two localities were investigated, here designated as area I and area II (figure 1). Area I is inside the Straumsvík cove itself, to the west of the pit which has been in use since 1984. Area II is outside the cove and east of the old pit, which has not been used for pot linings since 1985.

Six transects perpendicular to the shore were put down on area I (figure 1). The straigt-line distance between transects was 100 m. Transect 0 was placed on the outside of the pit itself, transect 100 was 100 m to the south etc. The substrate on the transects was similar, i.e. lava blocks with some loose boulders, especially on the lower parts of the transects. However, transect 100 would have been placed on the man-made rim of the pit. In order to make that transect comparable to the others it was moved 10 m to the north on to lava blocks. Transect 0 was on natural lava blocks, even though it was up against the man-made pit.

There is much diffuse fresh-water run-off in the whole of the area on which the transects were placed, although it appears to be greatest just west of transect 200. The salinity was measured in samples taken from the surface of the sea at all transects, usually both when the tide was rising and when it was falling. A flotation meter was used with an accuracy of about 0.5 promill. Results are shown in table I. Measurements were also made with a probe (accuracy within 0.1 promill) from the surface down to the bottom on three stations out on the cove (see figure 1). These measurements show that there is a slightly brackish layer floating on the fully saline sea. The thickness of this brackish layer is about 0.5 m (figure 2). From this one may conclude that when the sea is calm, each point on the shore is bathed in almost fresh water for about half an hour to a whole hour on a rising tide, before it is submerged in fully saline water. On a falling tide, similarly, each point is bathed in almost fresh water for half an hour to a whole hour before it emerges. The situation at Straumsvik is unusual for these reasons, and one would assume beforehand, that the species diversity of the intertidal seashore would be

lower than on similar shores elsewhere, as it is probable that some shore species may not tolerate so much contact with almost fresh water. On the other hand the measurements do not indicate any differences in salinities among the transects, even though the fresh-water run-off is especially conspicuous between transects 200 and 300.

Six stations were placed on each transect, the vertical distance between stations being 50 cm. The first station to be put down, the uppermost station on transect 500, was placed in the middle of the *Fucus spiralis/Pelvetia canaliculata* zone there. All uppermost stations on the other transects were then placed at the same height level. The uppermost station on each transect was designated as A, the next-uppermost, as B etc., and the lowermost station as F. The height level of the F-stations is taken as 0 datum, and the height of the A stations is therefore 2.5 m. Thus stations were not only placed on 6 transects perpendicular to the shore, they also form 6 horizontal transects from the pit. There are six stations on each horizontal transect, all at the same height level. The total number of stations in area I is 36.

Six quadrats were put down at each station as shown in figure 3. One quadrat for measuring cover was placed on each side of the station mid-point. A frame with a grid of 5 lines parallel to the shore and 10 line perpendicular to the shore was placed on the quadrats. The distance between lines was 10 cm, and the number of intersections was therefore 50. Percentage cover was measured by counting the number of intersections overlying each species. As there were two cover quadrats on each station the total number of points per station was 100. Percentage cover of all algae was measured and also of sessile animals, primarily *Mytilus edulis* and *Balanus balanoides*.

A 20 x 20 cm quadrat for the survey of animals was placed on the outside of each cover quadrat. A steel frame was placed on each quadrat, and all algae and animals removed from within the frame. A sharp knife was used to cut the algae along the edge of the frame and scrape the substrate. An additional 20 x 20 quadrat was placed to the outside of these quadrats for the survey of algae. All macroscopic algae were removed with a sharp knife. All samples were placed in plastic bags and transported thus to the laboratory.

The samples from the animal survey quadrats were washed in the laboratory with water or dilute isopropanolum. The algae were removed and placed on blotting paper to dry. The washing liquid was sieved through a 1 mm sieve and all animals retained by the sieve stored in 70% isopropanolum. The samples were then investigated using a stereo microscope and the animals identified to species when possible, and the number of individuals of each species counted. The samples from the algae survey quadrats were stored in 5% formaldehyde. For each sample a species list was then made. Large brown and red algae from these samples were dried on blotting paper for at least 48 hours and then weighed.

Five transects were placed on area II, the straight-line distance between transects being 100 m. Transect 0 was on the outside of an old pit, transect 100 was 100 m to the east etc. (see figure 1). Stations were placed on each transects with a vertical height difference of 50 cm. The first station put down was the lowermost station on transect 400 (designated as F), and all other stations were placed with reference to it. However, it proved impossible to put down stations as low as this station on the other transects due to surf, and on transect 0 it also proved impossible to work a station 50 cm above this. As a consequence there are four complete horizontal transects in this area. In addition there is one horizontal transect composed of the next lowermost stations extending from transect 100 to transect 400, and finally one station below the others on transect 400. The 0 datum in area II is the F station on transect 400. Its relation to the 0 datum used in area I is not known. The total number of stations in area II was 25.

The substrate in area II is composed of large boulders and lava blocks, much smoothed by the surf.

Fresh water appears to emerge almost everywhere on the shore, as in area I. Though the salinity measured at the transects was usually low, it was more variable than in area I. This is probably due to the shore being considerably more exposed here than in area I, and therefore at times there is more mixing between the fresh water and the sea.

The shore in area II is to some extend man-made landfill. By comparing aerial photographs taken 1956 (before the aluminium factory was built) and 1988 it can be seen that transect 0 is situated on the fill itself, whereas transects 100 and 200 are largely on natural substrate, and this is clearly so as far as transects 300 and 400 are concerned. There is a man-made boulder ridge above the shore around transects 0, 100 and 200, while there are natural lava blocks above the shore around transects 300 and 400. The substrate on all transects looks similar. The substrate on the landfill has evidently had sufficient time to acquire a natural look since the landfill was made.

Measurements of cover and taking of samples was similar to what was done in area I. This also applies to laboratory analysis, with the exception that there was insufficient time to allow for analysis of the algae survey samples (cf. the contract). Species identifications of algae are therefore preliminary to some extent.

Field work on area I was done May 8-22 1989, and on area II on June 2-7 1989. Agnar Ingólfsson, Ingi Agnarsson and Stefán Áki Ragnarsson took part in all stages of the work. Guðmundur Víðir Guðmundsson took part in the field work, and Karl Gunnarsson analysed the algae survey samples.

3. Results

3.1. Area I

3.1.1. Measurements of algal cover

All measurements of cover on transects 0, 100, 200, 300, 400 and 500 in area I are given in Appendix A. These measurements include algae as well as the sessile animals *Mytilus edulis* and *Balanus balanoides*. The cover of most species of algae on the 36 stations investigated is also shown on figures 4 - 7.

Ascophyllum nodosum is the dominant alga in the area. It is abundant over most of the area, except on the uppermost stations (figure 4), as is natural. Measurements of dry weight of this alga (figure 4) are in good agreement with the cover measurements. There are no discernible changes which can be related to the distance from the pit, but the species appears to be slightly less abundant on transect 300 than on other transects. It is also slightly less abundant on the lowermost stations than on the middle shore, but this is a pattern often seen on Icelandic shores.

The red alga *Polysiphonia lanosa* is closely associated with *Ascophyllum nodosum*. It grows exclusively as an epiphyte on *Ascophyllum*. This alga is rather scarce in Straumsvík, although occurring on all transects except transect 0 (figure 5). It does not show any significant changes with distance from the pit. The brown alga *Elachista fucicola* is in Straumsvik also an epiphyte on *Ascophyllum*. It is rather scarce, but there may be some tendency for it to increase in cover with increasing proximity to the pit. This tendency is not, however, statistically significant (Spearman Rank Correlation Coefficient=-0.252, $P>0.05$).

The green alga *Cladophora rupestris* is frequently dominant as an understorey algae with *Ascophyllum*. It is common at Straumsvík, and is clearly more abundant on the three transects that are closest to the pit than on the three transects that are further away (figure 5). This tendency is highly significant (Spearman Rank Correlation Coefficient=-0.423, $P<0.01$).

The brown alga *Fucus vesiculosus* is rather scarce in Straumsvík (figure 4), this being frequently so when its competitor, *Ascophyllum nodosum*, is abundant. Even though *Fucus vesiculosus* is present on all transects, its cover is significantly greater on those transects that are more distant from the pit than on the others (Spearman Rank Correlation Coefficient=+0.341, $0.05>P>0.01$). Measurements of dry weight of this alga correspond well with cover measurements, though changes in dry weight with distance from the pit are not significant. It is conspicuous that *Fucus vesiculosus* is almost confined to the lowermost two stations on the transects. The species is often common throughout the intertidal zone on Icelandic shores. It is possible that at Straumsvik

competition from *Ascophyllum* prevents it from growing except low down on the shore, where there is comparatively little *Ascophyllum*.

The red alga *Devaleraea ramentacea* only occurs rarely in area I (figure 5). Nevertheless its cover is significantly greater on those transects that are closer to the pit than on the more distant transects (Spearman Rank Correlation Coefficient=-0.366, $0.05>P>0.01$).

Other species of algae noted on the transects in area I do not show any significant changes with distance from the pit. The brown alga *Pelvetia canaliculata* occurs in small quantities on the uppermost stations (figure 6), and the brown alga *Fucus spiralis* has considerable cover on the two uppermost stations (figure 6). The crustose red alga *Hildenbrandia rubra* is quite common on the transects, especially around and somewhat above the midshore (figure 6). The crustose Corallinacea occurs sporadically on the lower portions of the transects (figure 6), and the red alga *Mastocarpus stellatus* has some cover on the lowermost stations (figure 7). Green membranous algae, difficult to identify in the field, also have considerable cover on the lowermost stations (figure 7). Analysis of the algae survey samples show that the chief species was *Ulvaria obscura*.

3.1.2. Dry weight of dominant algae

The dry weight of large algae, based on measurements from two 20 x 20 cm quadrats on each station, is given in Appendix B. Figure 4 shows the dry weight for *Ascophyllum nodosum* and *Fucus vesiculosus* on the transects. There is no significant change in dry weight of individual species with distance from the pit.

3.1.3. Species list of algae

A list of all species of algae identified from the 20 x 20 cm algae survey quadrats is given in Appendix C. No marked changes in species composition with distance from the pit are indicated. Figure 13 shows how the number of species per station is distributed over the transects. Species diversity in area I is further discussed in section 3.1.7.

3.1.4. Measurements of cover of animals

The cover of two species of animals, the mussel *Mytilus edulis* and the barnacle *Balanus balanoides*, was measured (see Appendix A). *Mytilus edulis* is common, but patchy, as this species frequently is. It is especially abundant on transects 0, 300 and 400, but there is no correlation between its cover and distance from the pit (figure 7). *Balanus balanoides* is scarce in Straumsvík and nowhere does it form continuous zones. It occurs in greatest quantities on transects 300 and 400 (figure 7) where also *Mytilus* is especially common (Spearman Rank Correlation Coefficient between *Balanus* and *Mytilus*=+0.539, $P<0.01$). There is no correlation between the cover of *Balanus* and distance from the pit.

3.1.5. Counts of animals

The results of counts of animals from the 20 x 20 cm quadrats are given in Appendix D. In addition the distribution of the more common species is shown in figures 8 - 10.

The winkle *Littorina saxatilis* is common throughout the area. Probably no other species is as widely distributed (figure 8). It is, however, not equally common everywhere, and its density increases with distance from the pit (Spearman Rank Correlation Coefficient= +0.393, 0.05>P>0.01). The lowest numbers occur on transect 200.

The amphipod *Gammarus oceanicus* is rather common on the lower parts of the more distant transects (figure 8). The correlation between density and distance from the pit is statistically significant (Spearman Rank Correlation Coefficient= +0.394, 0.05>P>0.01).

The isopod *Idotea granulosa* only occurred on the three transects closest to the pit (figure 9), and is quite common on the lower parts of these transects. The correlation between density and distance from the pit is statistically significant (Spearman Rank Correlation Coefficient=-0.543, P<0.01).

Oligochaetes are very abundant on the transects closest to the pit, especially on transect 0, and the correlation between density and distance from the pit is significant (Spearman Rank Correlation Coefficient=-0.415, P<0.01)(figure 10). No oligochaete was found on transect 300.

No other animal species showed a statistically significant correlation between density and distance from the pit. The winkle *Littorina obtusata* is common on all transects, especially on their lower portions as is to be expected (figure 8). The whelk *Thais lapillus* is found in some numbers on the lowermost portions of most transects (figure 9). The amphipod *Hyale nilssoni* is very common on all transects (figure 9), although somewhat less common on transect 300 than on the others. This amphipod lives among the algae, and the dominant alga *Ascophyllum nodosum* is less abundant here than elsewhere. The amphipod *Gammarus obtusatus* is rather common on most transects, but its distribution is patchy as is frequently the case with shore amphipods (figure 8). Isopods of the genus *Jaera* are common throughout the area, although not occurring on the uppermost stations (figure 9) in common with many other shore species. These isopods appear somewhat more common on the more distant transects, but this tendency is not statistically significant. It is only possible to identify the males of these isopods to species level, but males were scarce in the samples. Males of the species *Jaera albifrons* were identified from the total of 14 station distributed over all transects, whereas males of the species *Jaera prehirsuta* were only identified

from one station on transect 200 and one station on transect 400. The larvae of the chironomid *Cricotopus variabilis* occurred on the lower stations on all transects, often in considerable numbers. It was especially abundant on the lowermost station on transect 0 (figure 10), but there is no significant correlation between its density and distance from the pit. The staphylinid *Micralymma marinum* occurred sporadically throughout the area but in small numbers (figure 10).

3.1.6. Cluster analysis

When a cluster analysis is performed on the data (cover and density of species) from area I, using 1-Pearson correlation coefficients and average linkage and after density and cover measurements for each species have been ranked, the dendrogram seen in figure 11 is obtained. The uppermost stations (A-stations) on the six transects form a distinct group, which is connected to the next-uppermost stations on the three outer transects (300B, 400B and 500B) somewhat less distinctly. The F-stations (lowermost stations) on the six transects form a second rather distinct group together with the E-stations (next-lowermost stations) on transects 0, 100 and 200. If the A-stations are omitted and a cluster analysis performed on the remaining stations a dendrogram seen in figure 12 is obtained. It is now possible to identify four rather distinct groups. One group is composed of the three outermost B-stations (300B, 400B and 500B). A second group, somewhat heterogeneous, consists of most of the C and D-stations except 300D and 500D, and in addition the B-stations of the three transects closest to the pit. Five similar stations form the third group. These are the D and E-stations on the three most distant transects, with the exception of station 400D. The fourth group is heterogeneous and is composed of all F-stations and the three E-stations closest to the pit.

These similarity analyses clearly show a horizontal zonation pattern, as one would expect to find on shores of this type. Apart from this there seems to be a break of some sort between transects 200 and 300, especially evident for the B and E-stations.

3.1.7. Species diversity

Species diversity frequently decreases as one gets closer to a pollution source (see e.g. Hoare and Hiscock 1974). The pattern of species diversity is therefore worth considering. The index of species diversity used here is simply the number of species per station. It is clear that species diversity increases considerably downwards on the transects as is usually the case on shores (e.g. Ingólfsson 1976). There are on the other hand no indication that species diversity changes with distance from the pit (tables 3 and 4, figure 13).

3.2. Area II

3.2.1. Measurements of algal cover

All measurements of cover on transects 0, 100, 200, 300 and 400 in area II are given in Appendix E, and the distribution of the more common species is shown in figures 14 - 16. As already mentioned in the section on methods (section 2), the 20 x 20 cm algae survey samples have not yet been analysed, and confirmation of field identifications are sometimes lacking. In some cases field identifications were only very cursory.

The algal vegetation of area II is clearly very different from that of area I in accordance with the considerable differences in environmental conditions, both with respect to substrate and degree of exposure. Area II is quite open to the ocean swell, and it is to be expected that wave action is an important environmental factor for the organisms living there, whereas this is hardly so in area I. It is probable that the mixing of fresh-water run-off and sea-water is much greater here due to wave action than inside the cove itself, and a clear stratification (as seen inside the cove) is presumably rather rare. Probably, therefore, organisms living on the shore in area II should encounter fresh or very dilute brackish water considerably less often than organisms in area I.

The green alga *Acrosiphonia arcta* is a dominant species in area II (figure 14), but this species was only present in small quantities in area I. No correlation is apparent between cover of this alga and distance from the pit. The species is characteristic of exposed shores where there is some movements of boulders. Green membranous algae (possibly chiefly the species Ulvaria obscura) are also common throughout the area (figure 14) with no apparent relationship with distance from the pit.

Of the larger species the brown alga *Fucus distichus* is the most abundant in area II (figure 14). This species was only present in minute quantities in area I. The species is in Iceland especially characteristic of exposed shores, although often growing in sheltered shores as well. In area II the cover of this species decreases significantly with distance from the pit (Spearman Rank Correlation Coefficient=-0.505, $P<0.01$), the decrease being especially pronounced in the lower portions of the transects.

The brown alga *Pylaiella littoralis* is common throughout area II, with the exception of transect 0, but there is no significant correlation between the cover of this species and distance from the pit (figure 15).

Other species of algae are less common in area II than those mentioned above, but most of these show significant correlations with distance from the pit. One of these, the green alga *Enteromorpha* sp., shows increasing cover with increasing

distance from the pit (figure 15, Spearman Rank Correlation Coefficient=+0.541, $P<0.01$), but this species is almost confined to the transect furthest from the pit, transect 400. One another species, the red alga Porphyra sp., shows a similar tendency (figure 15), but this tendency is not statistically significant. This species is characteristic of exposed shores.

Most other species that are reasonably common show a decrease in cover with increasing distance from the pit. The brown alga *Elachista fucicola* occurs in some quantities on those three transects that are nearest to the pit, but scarcely on the more distant transects (figure 25). The correlation between cover and distance from pit is significant (Spearman Rank Correlation Coefficient=-0.572, $P<0.01$). An unidentified red membranous alga only occurs on transects 0 and 100 (figure 16, Spearman Rank Correlation Coefficient=-0.672, $P<0.01$), and the brown alga *Ascophyllum nodosum* is also confined to these two transects, where it occurs in small quantities (figure 14, Spearman Rank Correlation Coefficient=-0.711, $P<0.01$). The same applies to the red alga *Polysiphonia urceolata* (figure 16, Spearman Rank Correlation Coefficient=-0.519, $P<0.01$) and the red crustose alga *Hildenbrandia rubra* which is especially abundant on transect 0 (figure 16, Spearman Rank Correlation Coefficient=-0.671, $P<0.01$). The red alga *Mastocarpus stellatus* only occurs on transect 0, at the pit (figure 16, Spearman Rank Correlation Coefficient=-0.548, $P<0.01$). This species is characteristic of exposed shores.

3.2.2. Measurements of cover of animals

All measurements of cover of sessile animals are given in Appendix E. The mussel *Mytilus edulis* is fairly common throughout the area (figure 17), although its cover nowhere approaches that which is shows in area I. There is no correlation between its cover and distance from the pit. The barnacle *Balanus balanoides* also occurs on all transects, but its cover decreases significantly with distance from the pit (figure 16, Spearman Rank Correlation Coefficient=-0.497, $P<0.01$). Its cover is, however, everywhere comparatively small.

3.2.3. Counts of animals

Results of counts of animals in 20 x 20 cm quadrats from area II are given in Appendix F, and the distribution of the more common species is in addition shown in figures 18 - 20. Some of the species proved to be common throughout the area. The amphipod *Hyale nilssoni* was common on all transects, especially on their upper portions (figure 18). There was no correlation between its density and distance from the pit. Oligochaetes were very common on all transects (figure 19). The larvae of the chironomid *Cricotopus variabilis* were also common on all transects (figure 19), considerably more common than in area I. Their density, however, decreases significantly with distance from the pit (Spearman Rank Correlation Coefficient=-0.396, $0.05>P>0.01$). The winkle *Littorina saxatilis*

occurred on all transects, although its distribution was somewhat patchy (figure 19). There was no correlation between density and distance from the pit.

Other animal species were largely confined to the transects nearest the pit. The amphipod *Gammarus ocanicus* is common on the lower portions of transects 0, 100 and 200, but only occurs on one stations on the more distant transects (figure 18, Spearman Rank Correlation Coefficient=-0.461, $0.05>P>0.01$). The amphipod *Gammarus obtusatus* also snows a significant correlation between its density and distance from the pit (Spearman Rank Correlation Coefficient=-0.448, $0.05>P>0.01$), but this species is less abundant (figure 18). The winkle *Littorina obtusata* only occurs on transects 0, 100 and 200 and is rather scarce (figure 19). Its density decreases significantly with distance from the pit (Spearman Rank Correlation Coefficient=-0.543, $P<0.01$). The gastropod *Skeneopsis planorbis* has a similar distribution, although it occurs in considerable numbers at two stations (figure 20, Spearman Rank Correlation Coefficient=-0.430, $0.05>P>0.01$). The isopod *Idotea pelagica* is very common on transect 0, at the pit, but it scarcely occurs on the most distant transects, transects 300 and 400 (figure 18). Its density decreases significantly with distance from the pit (Spearman Rank Correlation Coefficient=-0.678, $P<0.01$). This species is characteristic of exposed shores and was not found at all in area I, inside the cove. The whelk *Thais lapillus* only occurred on the two transects closest to the pit, and only in small numbers (figure 20). Its density is significantly correlated with distance from the pit (Spearman Rank Correlation Coefficient=-0.463, $0.05>P>0.01$).

3.2.4. Cluster analysis

When a cluster analysis is performed on the data (cover and density of species) from area II, using 1-Pearson correlation coefficients and average linkage method and after density and cover measurements for each species have been ranked, the dendrogram seen in figure 21 is obtained. The uppermost two stations on the five transects form a distinct group, with the exception of station 400B which is not included in the group. The remaining stations form two groups. One of the groups consist exclusively of stations from the three transects nearest to the pit, whereas the other group is composed of stations from the two outermost transects, transects 300 and 400. This analysis therefore indicates changes on the lower portions of the transects with distance from the pit. It can furthermore be seen, that the uppermost two stations on transect 0, at the pit, are separated from the topmost two stations of the other transects. If the uppermost two stations, of the transects, A and B, are omitted from the analysis and the remaining data re-ranked, the results seen in figure 22 are obtained. The two lowermost stations on transect 0 (0C and 0D) are somewhat separated from the others. A second group is formed by stations 100C, 100D and 200D. A third group is formed by 100E, 200C, 200E, 300D and 300E. Finally, a fourth group includes all stations from transect 400 (400C, 400D, 400E, 400F) in addition to station 300C.

This analysis is therefore in agreement with the analysis of the distribution of individual species, and strongly indicates that considerable changes occur in area II with increasing distance from the pit.

3.2.5. Species diversity

It is noteworthy, that in area II there is no correlation between the number of species per station and vertical height, as is usually to be found on shores (cf. also area I). On the other hand it can be seen from figure 23 and table 5 that species diversity decreases with distance from the pit, this tendency being highly significant (Spearman Rank Correlation Coefficient=-0.789, $P<0.01$). The greatest changes in species diversity occur between transects 0 and 200, while transects 200, 300 and 400 do not differ greatly.

4. Discussion

There is almost no information available on the kind of effects that refuse from aluminium smelters may have on marine life (Ellis 1989). The present survey around the Straumsvik aluminium plant was especially directed towards detecting detrimental effects that might be discernible by a decrease in species diversity and by a decrease in the abundance of some individual species as one approaches the pollutant source. Similar kind of changes were looked for in a survey of marine life around an aluminium plant at Husnes in Kvinnherad, Norway (Rygg and Green 1981). It is conceivable, however, that pollution from a dumping pit for spent pot linings might enhance the environmental conditions for some species through the elimination of competing species. It is, however, very difficult to conceive that a dumping pit might have general beneficial effects on the organisms in its surroundings.

4.1. Area I

In area I discernible changes in the community of organisms with distance from the dumping pit are few. Four species increase in abundance towards the pit, i.e. the algae *Cladophora rupestris* and *Devaleraea ramentacea*, the isopod *Idotea granulosa* and oligochaetes. In all instances the change is most abrupt between transects 200 and 300, and two of the species, *Cladophora* and *Idotea*, do not occur at all on the more distant transects (300, 400 and 500). Three species on the other hand decrease significantly towards the pit, i.e. the alga *Fucus vesiculosus*, the winkle *Littorina saxatilis* and the amphipod *Gammarus oceanicus*. In the case of *Fucus* and *Gammarus* the most abrupt changes occur between transects 200 and 300 as before, while this is not so clear in case of *Littorina*. The cluster analysis also indicates some sort of boundary between transects 200 and 300. Many species occur rather evenly throughout the area, and there are no noticeable changes in species diversity with distance from the pit.

It is unlikely that the above mentioned changes result from pollution from the dumping pit, in particular as these changes do not include any reduction in species diversity. Furthermore, the community does not change gradually as if there was a pollutant gradient from the pit, but there is rather a somewhat abrupt change between transects 200 and 300. Both points also make it unlikely that the observed changes might be the result of organic pollution from salmon farming cages located between the harbour quay and the dumping pit. There is in addition no correspondence between the distributional pattern of species seen in area I and what is known of the response of species to organic pollution. In the fjord of Skerjafjördur, for example, the winkle *Littorina saxatilis* appears to benefit considerably from some sewage pollution, whereas in area I at Straumsvík, it increases in abundance away from the dumping pit (and the salmon cages). The same can be said of the amphipod *Gammarus oceanicus* (Ingólfsson 1977b, Ármannsson 1978). On the other hand the green alga *Cladophora rupestris* seems to be sensitive to sewage pollution (Gunnarsson and Þórisson 1976), but in area I, Straumsvík, it increases in abundance towards the dumping pits (and hence the salmon cages).

It seems most probable that the changes mentioned above are the result of different degrees of exposure in different parts of Straumsvík. The alga *Fucus vesiculosus* and the amphipod *Gammarus oceanicus* are known to be especially abundant on somewhat exposed shores (Ingólfsson 1977b). It is possible that the transects closest to the dumping pit are on shores that receive more shelter from the harbour breakwater than the more distant transects, where these two species mostly occur.

4.2. Area II

It is clear that the community of the shore in area II changes considerably with distance from the dumping pit. Many species decrease in abundance away from the pit (*Fucus distichus, Ascophyllum nodosum, Elachista fucicola, Mastocarpus stellatus, Hildenbrandia rubra*, an unidentified red membranous alga, *Polysiphonia urceolata, Balanus balanoides, Littorina obtusata, Cricotopus variabilis, Skeneopsis planorbis, Idotea pelagica, Thais lapillus, Gammarus oceanicus, G. obtusatus*). Some species show a pattern that does not seem to be related to the distance from the pit (*Acrosiphonia arcta, Porphyra* sp. cf. *Ulvaria obscura, Pylaiella littoralis, Mytilus edulis, Hyale nilssoni*, Oligochaetes, *Littorina saxatilis*). Only a single species, *Enteromorpha* sp. shows increasing abundance away from the pit. The cluster analysis clearly shows that considerable changes of the community occur with distance from the pit. The species diversity, as must be evident, decreases considerably with increasing distance from the pit.

The above results do not give any indication that pollution from the dumping pit is affecting the shore community in area II. The results, however, indicate that there could be a source of pollution near the eastern border of area II, i.e. in the neighbourhood of transect 400.

The salmon farm Pólarlax is located about 350 m to the east of transect 400, but the farm ceased operation in 1989. It is probable that considerable organic waste reached the shore from this salmon farm, and it would not be unexpected to find some effects of organic pollution near the farm. However, several points argue rather against organic pollution from this farm being the reason for the observed changes in area II. These changes appear for example to be too large, in view of the considerable mixing that must occur between the liquid organic waste and the sea at this exposed locality. Sea currents in this area are little known, but the mean current is probably towards east (cf. Malmberg 1968), which should reduce the possible effect of organic pollution from the salmon farm on the shore community in area II. Furthermore, among those species decreasing in abundance towards the salmon farm (and away from the dumping pit) there are both species known to be intolerant of organic pollution (*Ascophyllum nodosum, Elachista fucicola*) and species which are known to benefit from organic pollution, if not to heavy (*Balanus balanoides, Fucus distichus, Littorina obtusata*) (Gunnarsson and Þórisson 1976, Ármannsson 1978, Ingólfsson 1977b).

Until recently cooling water from the high voltage switchyard building and from the rectifiers was piped onto the shore near transect 400. The temperature of this water was around 15°C (Guðmundur H. Guðmundsson, pers. comm.). This water, however, has been piped to the salmon farm after it started operating. It must be considered unlikely that this cooling water could cause extensive changes in the community over such a large area. The temperature of the water is not high enough for this, and the mixing with the sea-water too rapid. It should be born in mind that some cooling water from the cast houses is piped onto the shore near transect 100. Its temperature is variable, but generally less than 20°C.

The dumps of the city of Hafnarfjörður were located near transect 100 (according to aerial photographs from 1962 and 1966) from about 1960 to 1968 or so. It seems possible that some poisonous chemicals are still leaking to the sea from these old dumps. The changes which are seen in the community in area II do not, however, seem to revolve around the spot where the dumps were located, at transect 100.

An additional possibility is that the average wave action increases in the area away from the dumping pit. Few of the observed changes in the community argue against this hypothesis. It could, however, be pointed out, that the amphipod *Hyale nilssoni*, which in general seems to be rather intolerant of surf (Ingólfsson 1977), was common throughout the area. It is clear on the other hand that many of the species common in the area are characteristic of wave-exposed shores (e.g. *Fucus distichus, Acrosiphonia arcta, Porphyra* sp., *Mastocarpus stellatus, Idotea pelagica*).

It is possible that the cause of the decrease of several species with distance from the pit is the decrease of some key species that profoundly affects the

environment. The most probable key species is the brown alga *Fucus distichus*, but nothing is however known about how it influences the environment of other species.

The results give indications of an environmental gradient which causes the decrease of many species with increasing distance from the dumping pit towards the east. It is difficult to connect this gradient with the pit, and other hypothesis do not seem plausible.

5. Summary

A survey of the biota of the intertidal shore was done in two areas around the aluminium smelter at Straumsvík during May and June 1989. Area I was close to a dumping pit, which has been in operation since 1984 and is located within the Straumsvík cove itself. Area II is to the east of the Straumsvík cove near a dumping pit which has not been used for dumping pot linings since 1985. The results did not indicate that the dumping pits had detrimental effects on the shore communities. The results indicated, however, that environmental conditions deteriorated in area II towards east away from the dumping pit, but no obvious reason for this was seen.

6. Final remarks

Even though the present results did not in any way indicate that the dumping pits had detrimental effects on the shore communities, it would be desirable to do the following in addition:

(1) To analyse further the algal samples collected from area II.

(2) To add 3-4 transects in area II between transect 400 and the salmon farm in order to investigate the possible effects of the farm on the shore communities.

(3) To measure the concentration of selected pollutants in shore organisms, both in area I and area II. It would be desirable to measure both possible pollutants from the aluminium smelter and in addition in area II to measure chemicals, which possibly might leak from the old dumps close to transect 100.

7. References

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Table 1. Salinity measurements at shore transects in Straumsvik, area I. Samples were taken at the surface and measurements made with a flotation meter. Figures show salinities in promills.

Trans 0		Trans 100		Trans 200		Trans 300		Trans 400		Trans 500	
Date hour	sal	Date hour	sal	Date hour	sal	Date hour	sal	Date hour	sal	Date hour	sal
22.5 11.20	17.7	18.5 09.45	8.0	17.5 09.15	16.2	16.5 10.30	3.5	11.5 13.55	5.2	10.5 16.40	4.4
22.5 13.40	17.1	18.5 12.00	4.2	17.5 12.45	11.6	16.5 11.50	2.2	11.5 16.30	2.9	23.5 12.05	3.2
		18.5 13.30	3.2	24.5 14.30	9.5	24.5 12.10	4.6	23.5 14.15	3.1	23.5 13.45	4.1
		22.5 14.30	3.7	24.5 15.35	5.7	24.5 14.00	2.4	23.5 15.40	2.1		

Table 2. Salinity measurements at shore transects in Straumsvik, area I. Samples were taken at the surface and measurements made with a flotation meter. Figures show salinities in promills.

Trans 0		Trans 100		Trans 200		Trans 300		Trans 400	
Date hour	sal	Date hour	sal	Date hour	sal	Date hour	sal	Date hour	sal
6.6. 11.10	18.4	6.6. 14.10	9.6	7.6. 13.00	1.3	5.6. 09.55	19.2	2.6. 10.40	1.0
6.6. 13.30	6.2	6.6. 16.00	5.3	7.6. 13.45	5.7	5.6. 13.00	1.0	2.6. 13.45	12.4

Table 3. Number of species of animals and algae per station in area I, based on two 1 x 0.5 m cover quadrats and two 20 x 20 cm animal survey quadrats per station.

Station	Transect					
	0	100	200	300	400	500
A	6	5	5	4	7	5
B	11	10	8	6	12	8
C	12	8	10	7	10	9
D	15	12	11	13	11	14
E	17	15	16	16	16	16
F	20	18	23	17	15	19

Table 4. Number of species of algae per station in area I, based on two 20 x 20 cm algae survey quadrats per station.

Station	Transect					
	0	100	200	300	400	500
A	3	11	2	6	9	11
B	6	5	6	6	5	12
C	5	7	4	2	7	9
D	7	15	5	5	4	8
E	17	10	13	17	4	17
F	28	22	18	11	15	19

Table 5. Number of species of animals and algae per station in area II, based on two 1 x 0.5 m cover quadrats and two 20 x 20 cm animal survey quadrats per station.

Station	Transect				
	0	100	200	300	400
A	17	19	12	11	10
B	19	15	12	11	10
C	20	14	11	13	11
D	23	10	13	5	7
E	-	17	12	4	11
F	-	-	-	-	11

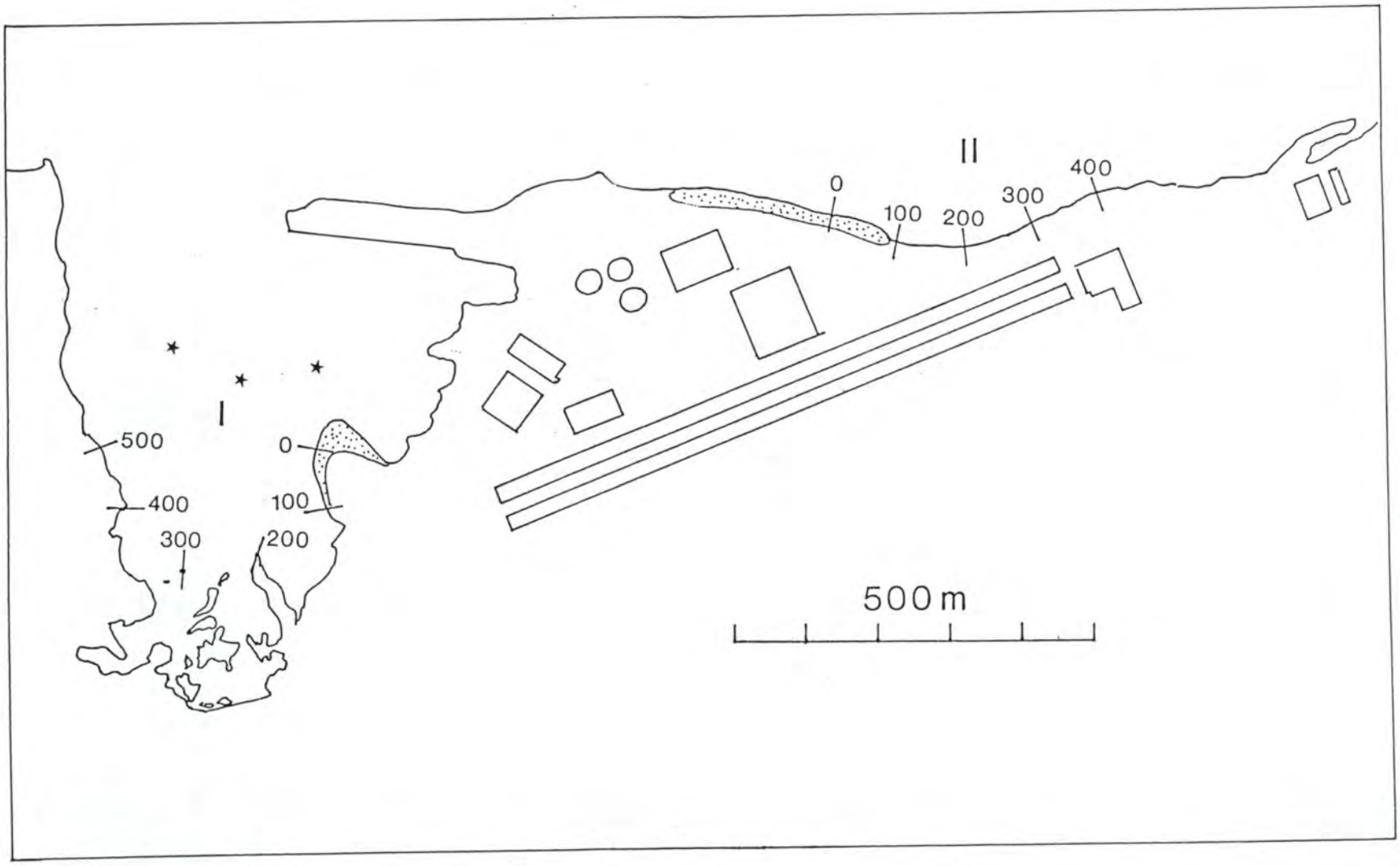


Figure 1. Straumsvík and surroundings. The location of transects on areas I and II is shown. Dumping pits are stippled. Stars indicate position of salinity profiles.

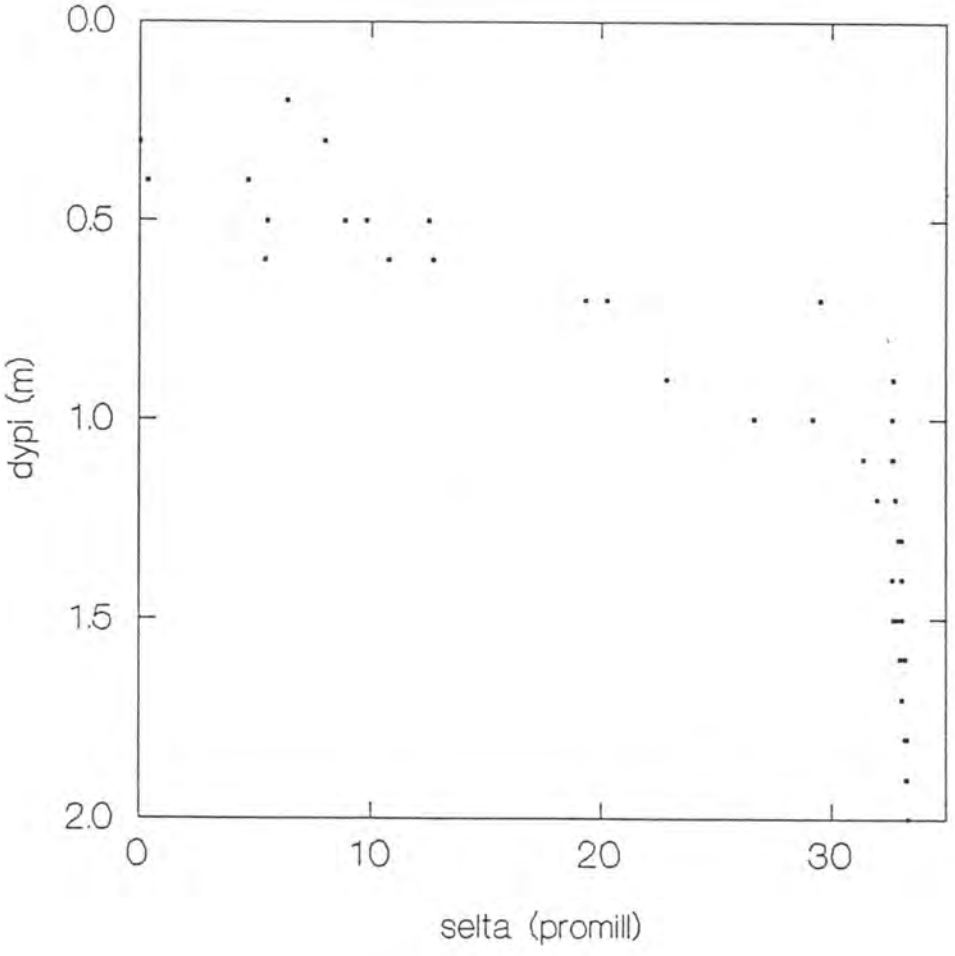


Figure 2. Salinities measured on three vertical profiles in Straumsvík (see figure 1) from the surface down to a depth of 2 m on June 28, 1989.

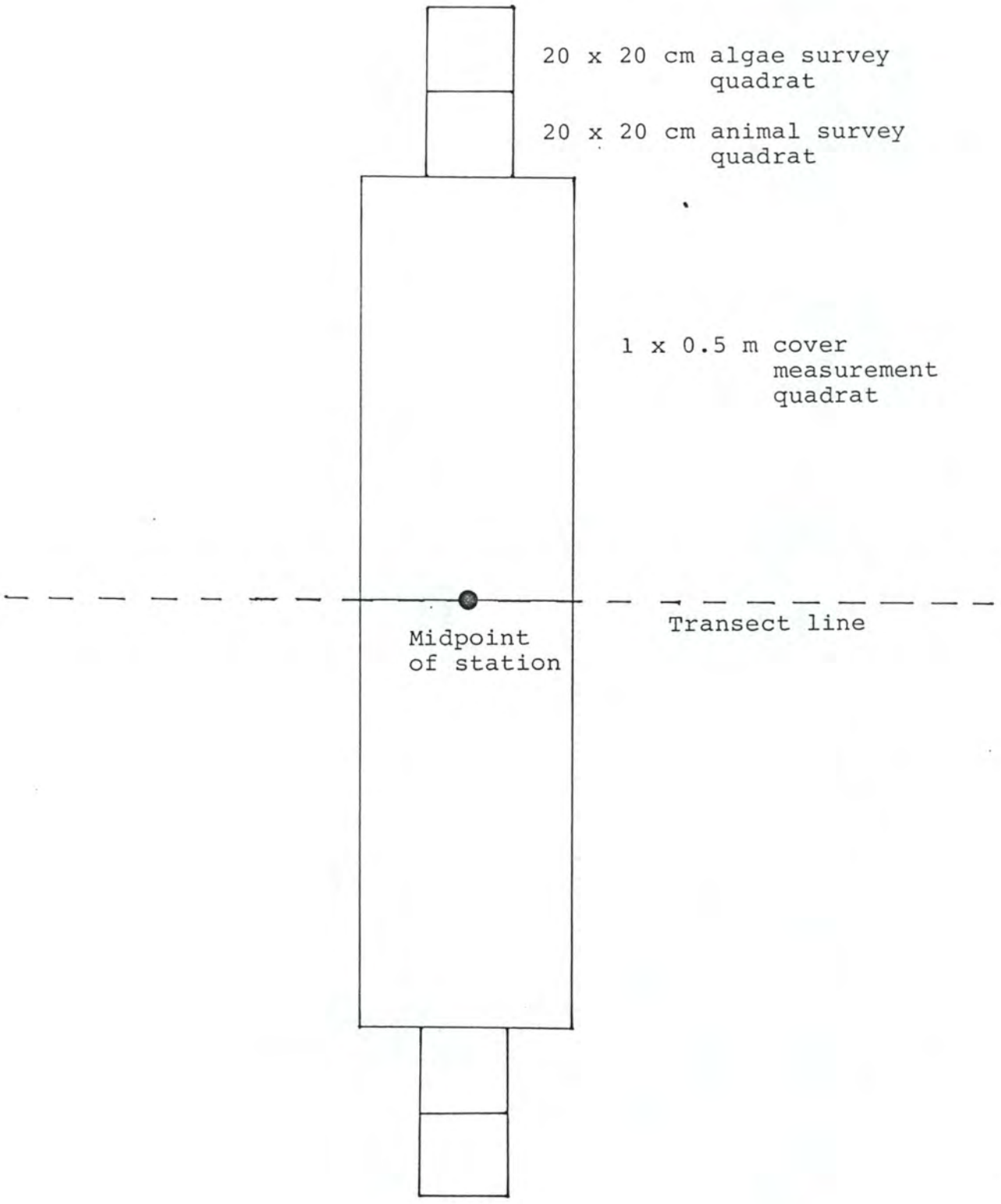


Figure 3. The position of cover and sampling quadrats on the shore transects.

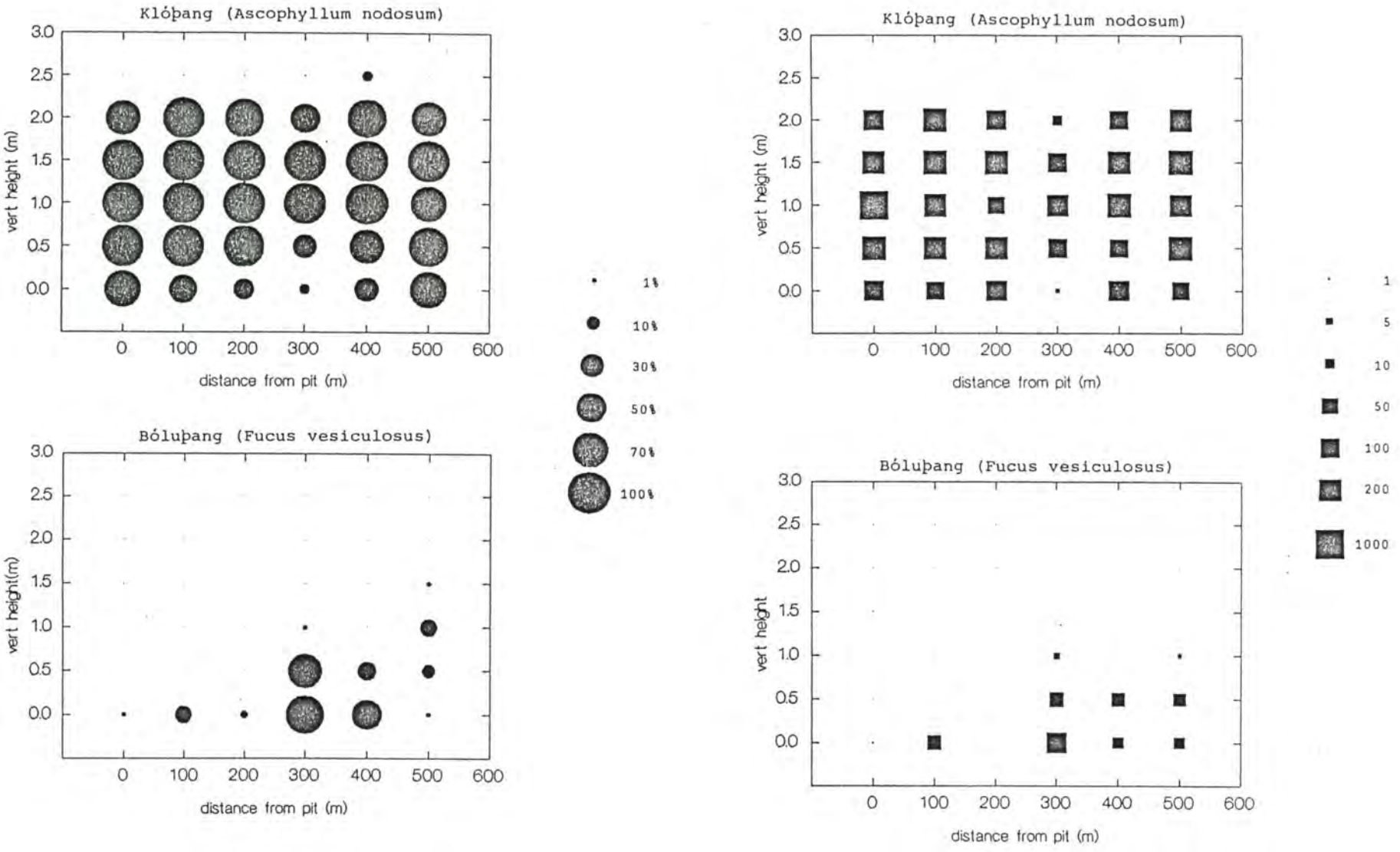


Figure 4. Cover (%, on the left) and dry weight (g/800 cm², on the right) of the brown algae *Ascophyllum nodosum* and *Fucus vesiculosus* on stations in area I, Straumsvík, May 1989.

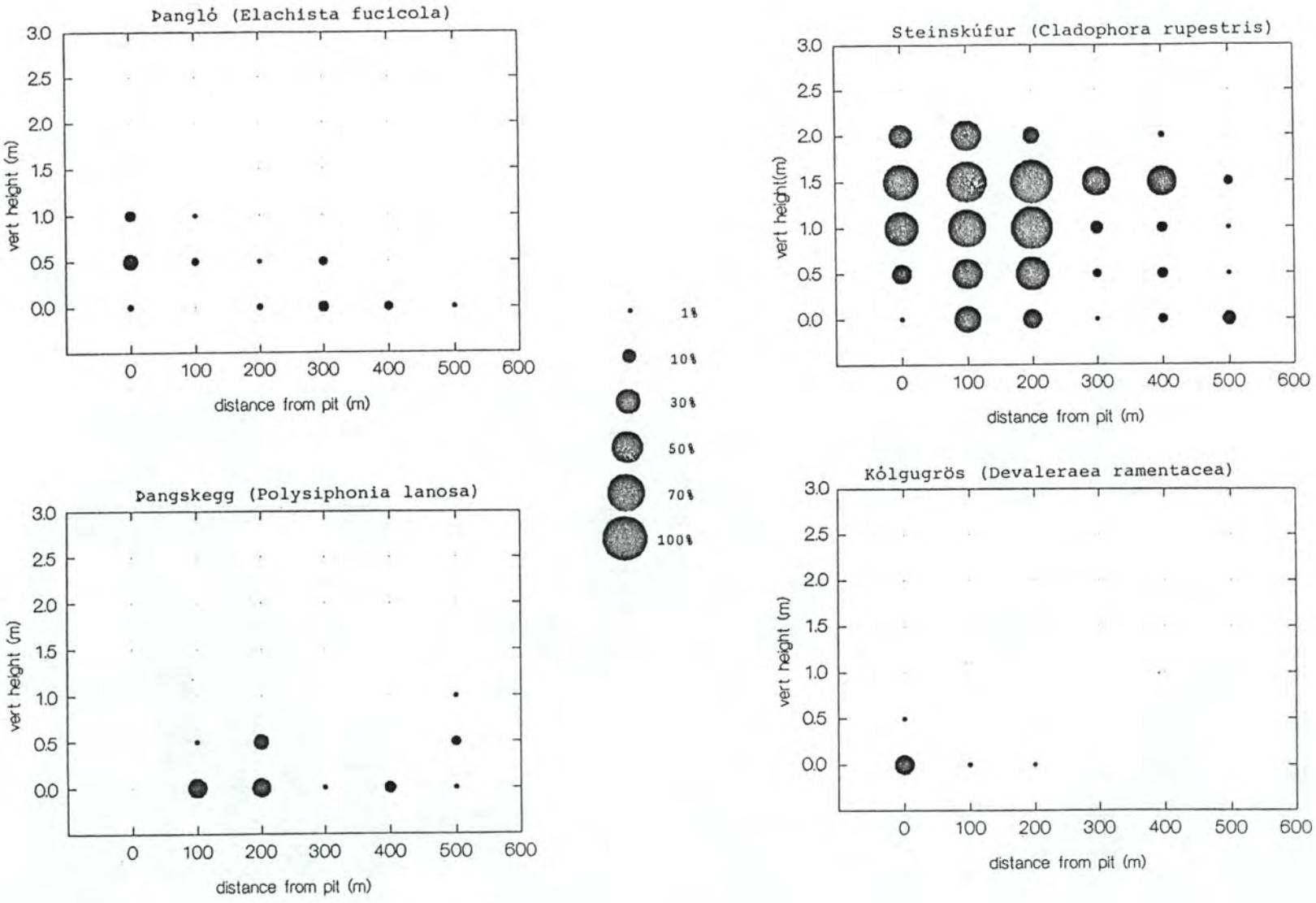


Figure 5. Cover (%) of the algae *Elachista fucicola*, *Polysiphonia lanosa*, *Cladophora rupestris* and *Devaleraea ramentacea* on stations in area I, Straumsvík, May 1989.

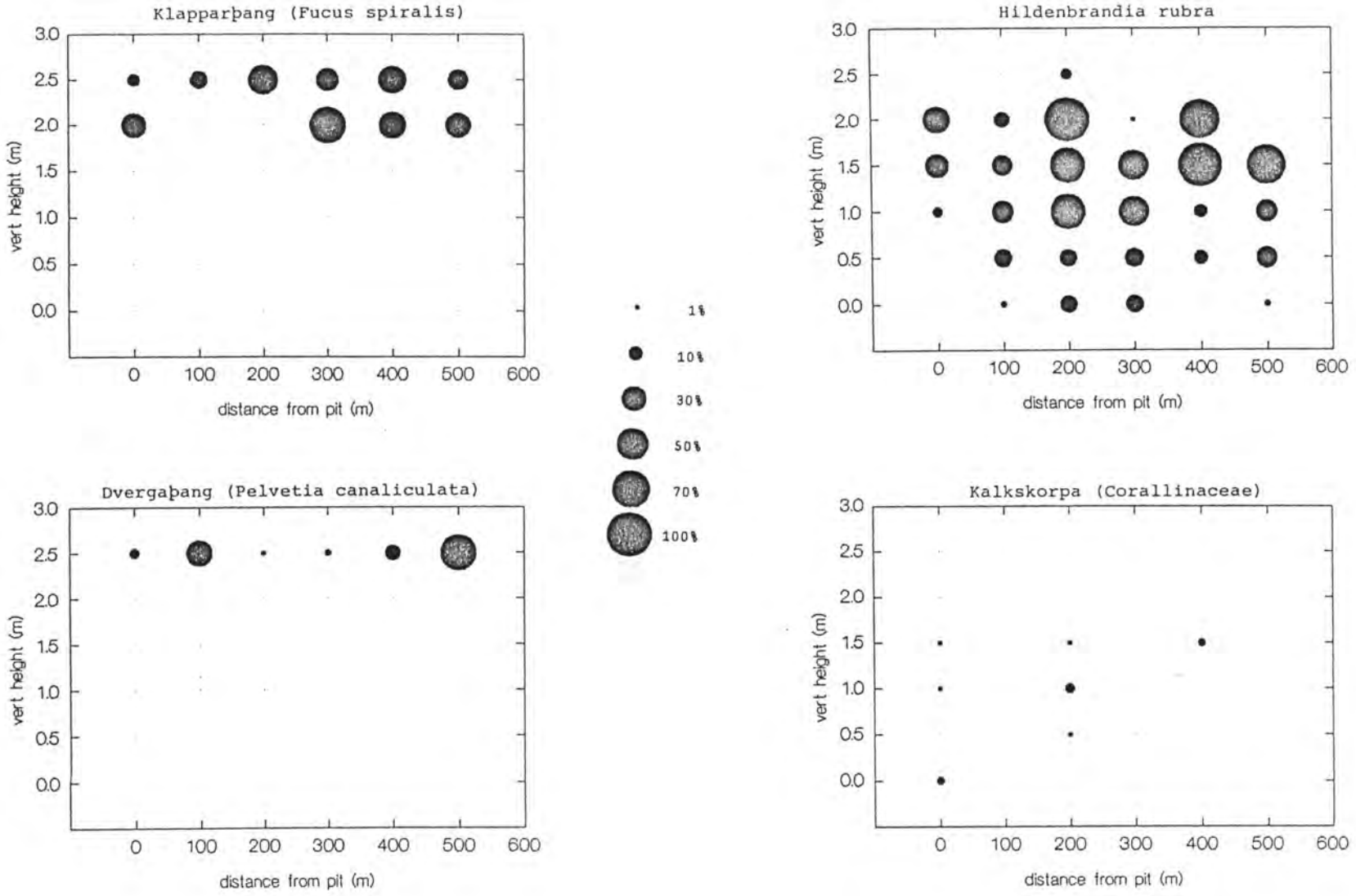


Figure 6. Cover (%) of the brown algae *Fucus spiralis* and *Pelvetia canaliculata* and of the red crustose algae *Hildenbrandia rubra* and Corallinaceae on stations in area I, Straumsvík, May 1989.

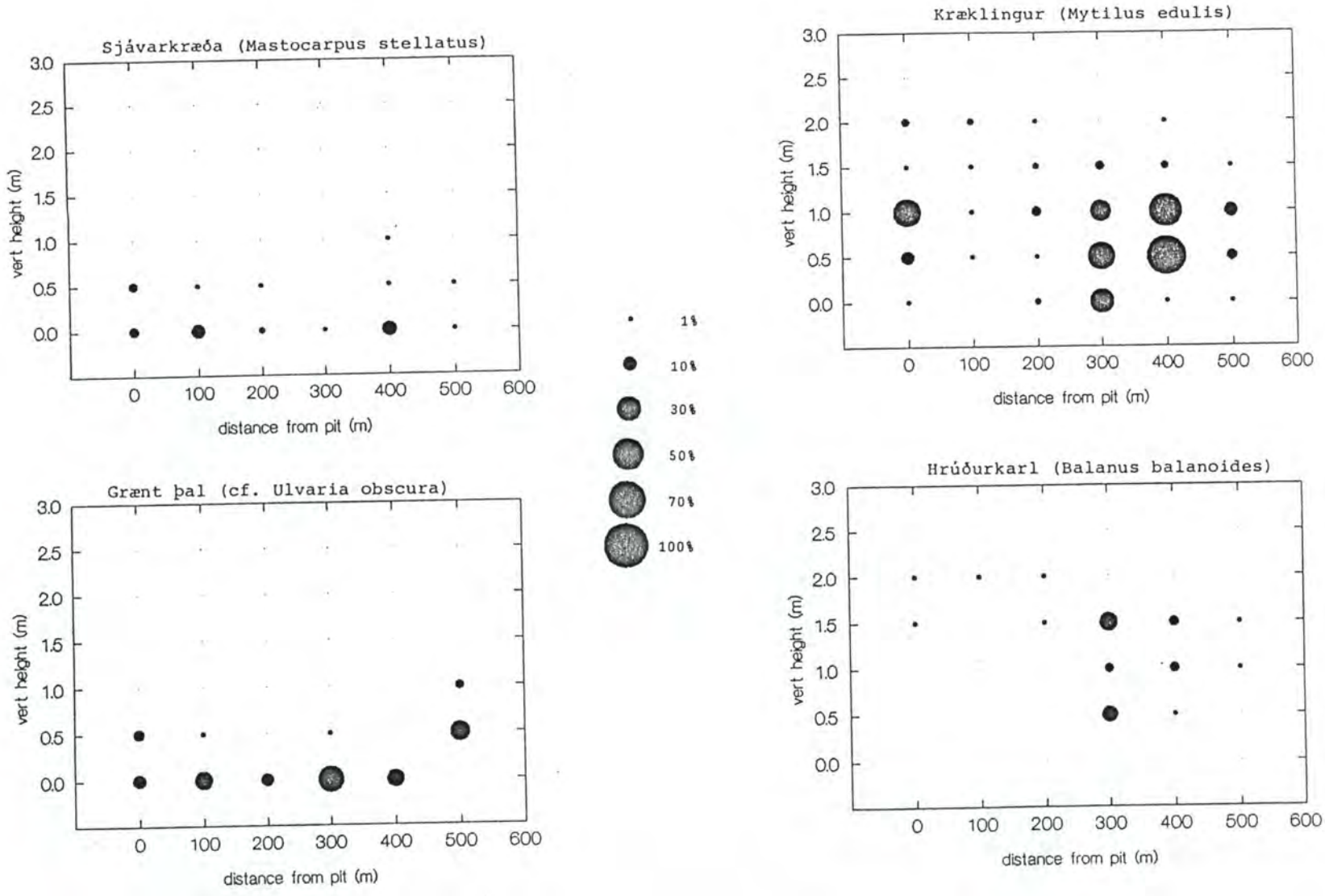


Figure 7. Cover (%) of the algae *Mastocarpus stellatus* and cf. *Ulvaria obscura* and of the sessile animals *Mytilus edulis* and *Balanus balanoides* on stations in area I, Straumsvík, May 1989.

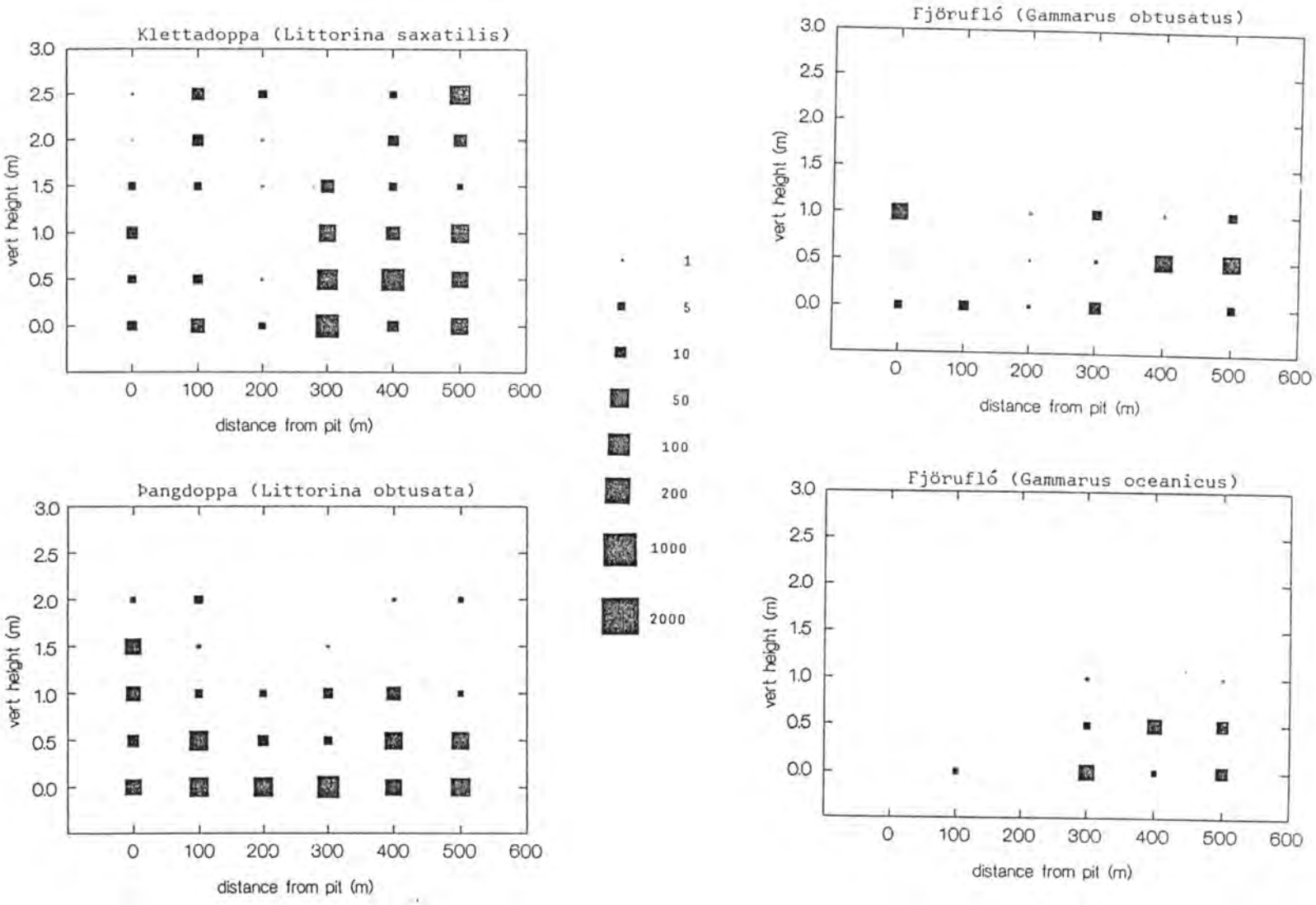


Figure 8. Number of individuals per station of the winkles *Littorina saxatilis* and *Littorina obtusata* and of the amphipods *Gammarus obtusatus* and *Gammarus oceanicus* in area I, Straumsvík, May 1989. The area investigated per station is 800 cm².

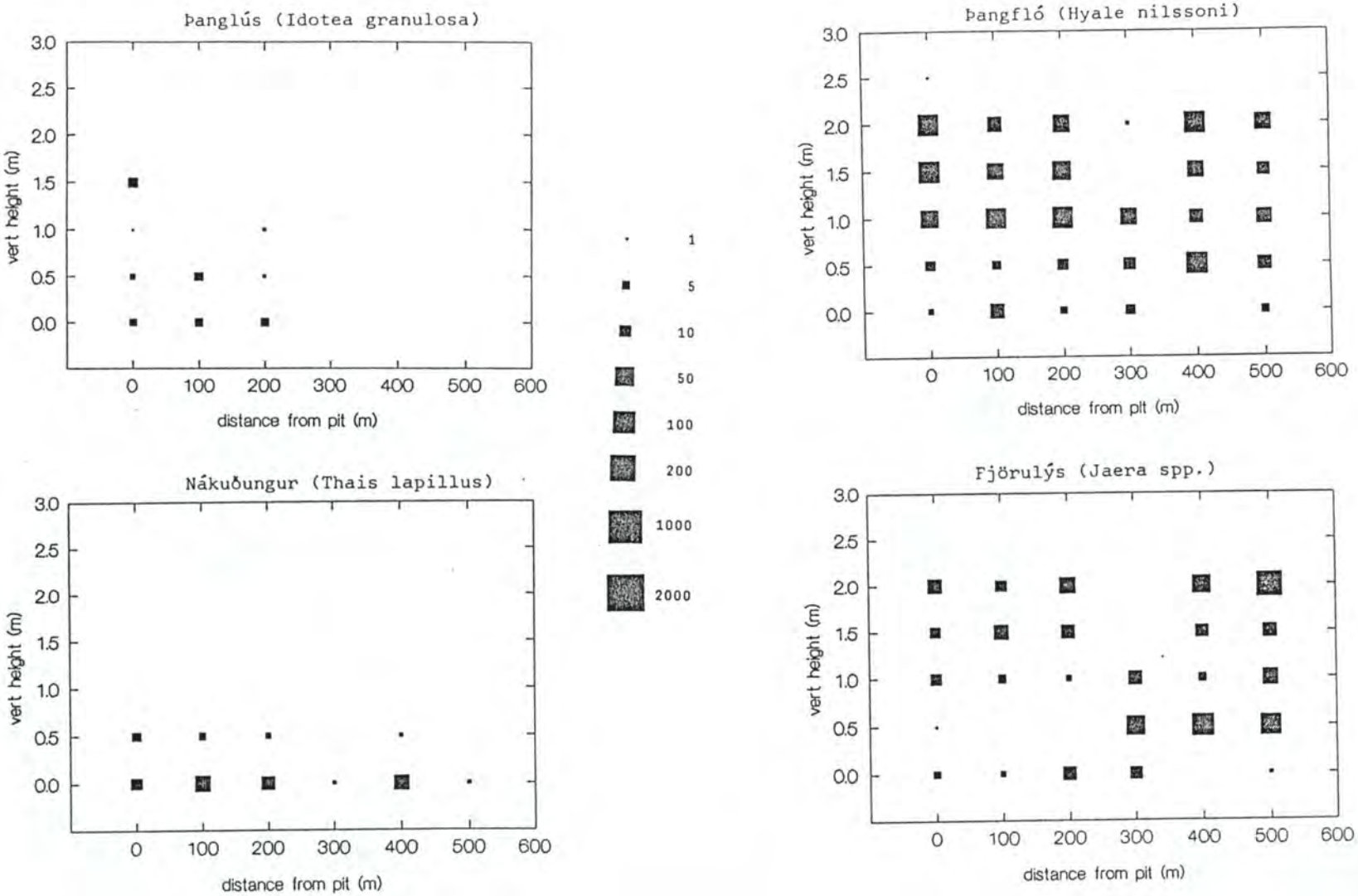


Figure 9. Number of individuals per station of the isopods *Idotea granulosa* and *Jaera* spp., of the amphipod *Hyale nilssoni* and of the whelk *Thais lapillus* in area I, Straumsvík, May 1989. The area investigated per station is 800 cm².

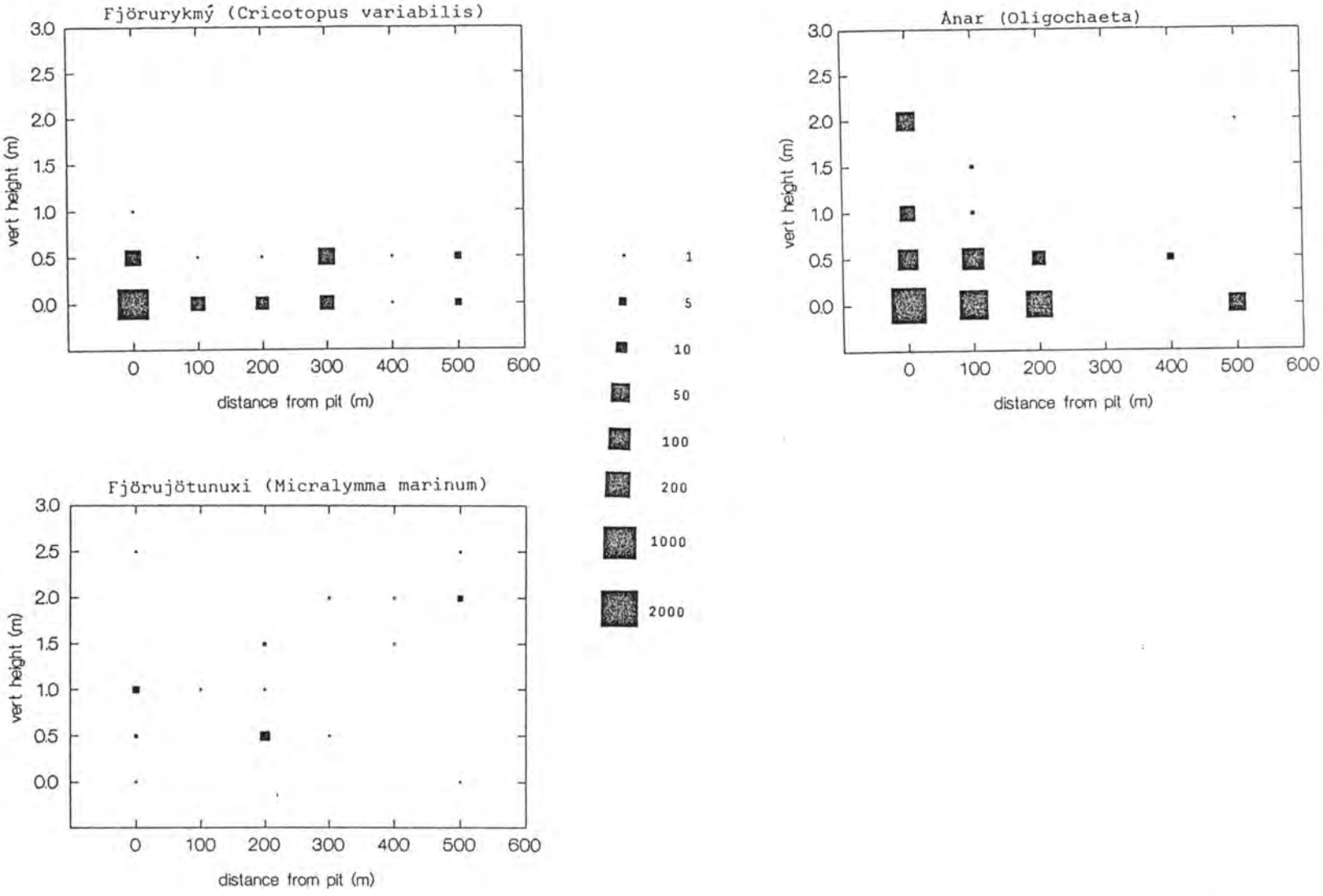


Figure 10. Number of individuals per station of the chironomid *Cricotopus variabilis*, the staphylinid *Micralymma marinum* and of oligochaetes in area I, Straumsvík, May 1989. The area investigated per station is 800 cm².

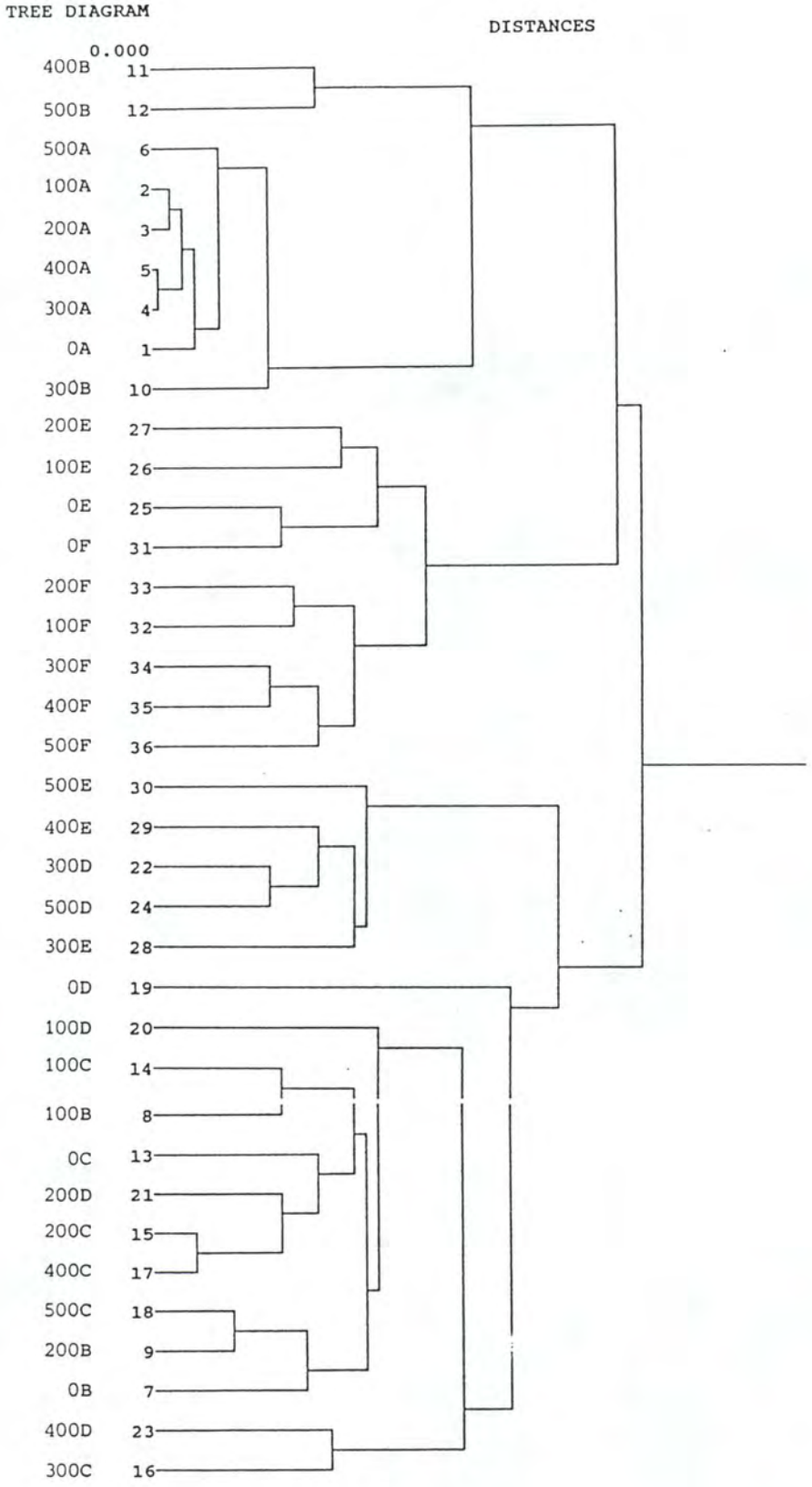


Figure 11. A dendrogram showing clustering of stations in area I, Straumsvík. Distance metric is 1-Pearson correlation coefficient and the linkage is average. Cover percentages and animal numbers have been ranked for each species before analysis.

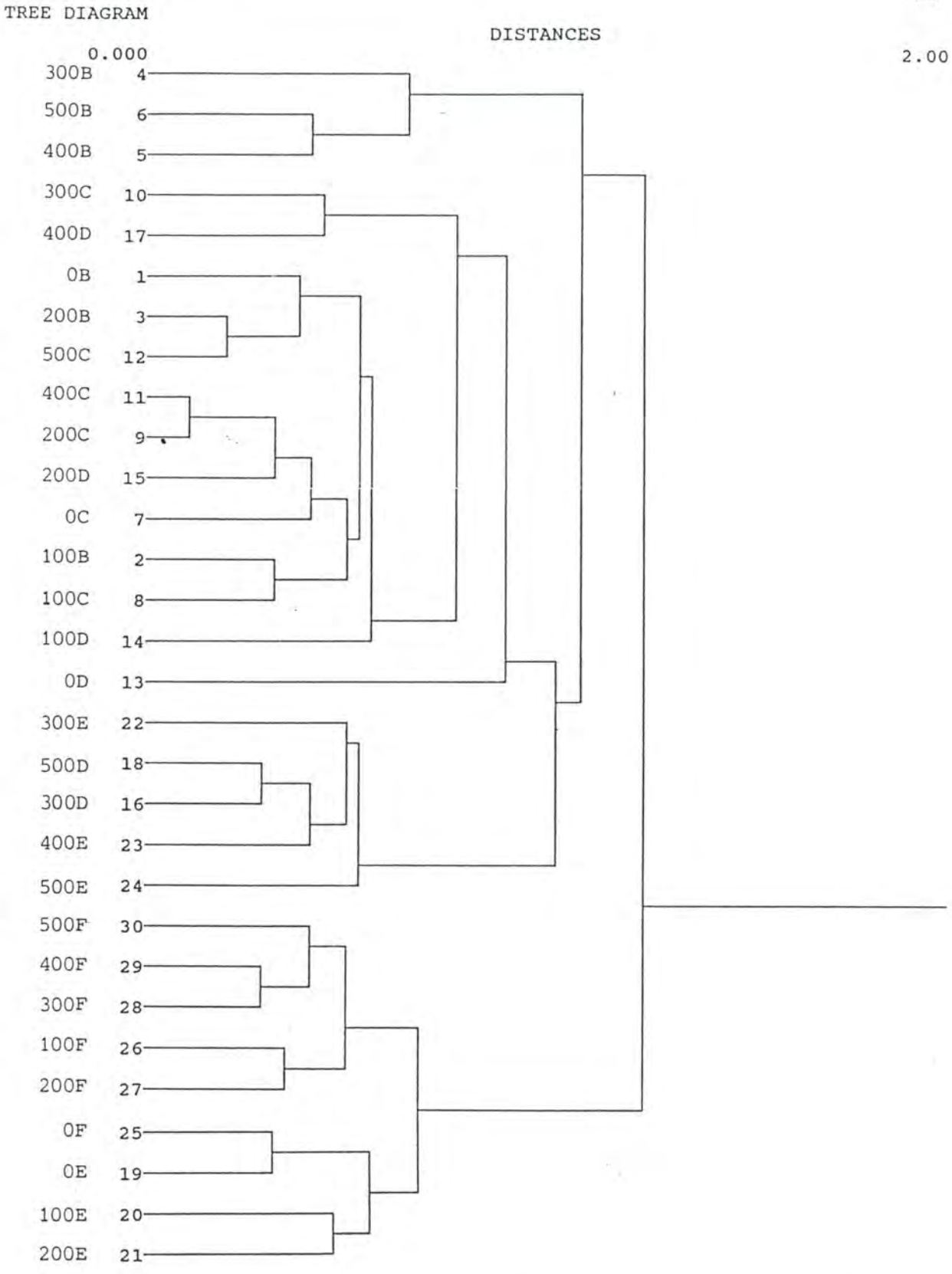
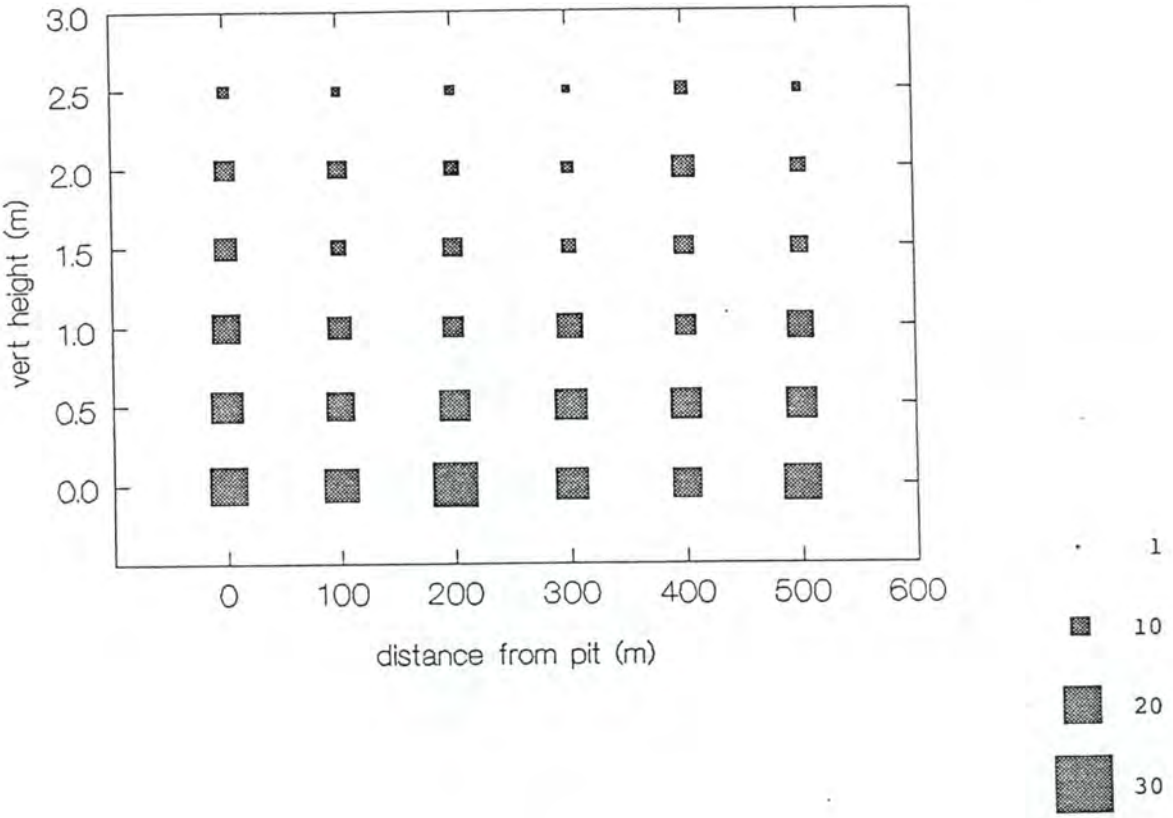


Figure 12. A dendrogram showing clustering of the B-F stations in area I, Straumsvík. Distance metric is 1-Pearson correlation coefficient and the linkage is average. Cover percentages and animal numbers have been ranked for each species before analysis.



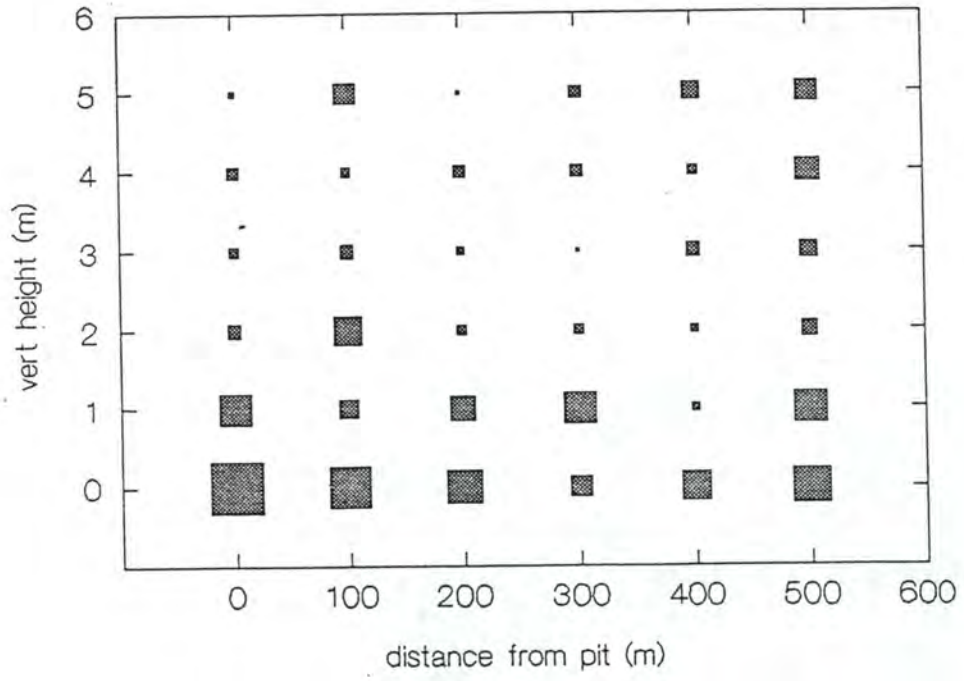


Figure 13. Number of species per station in area I, Straumsvík. The upper figure shows the number of species of algae and animals on two 1 x 0.5 m cover quadrats and on two 20 x 20 cm animal survey quadrats per station. The lower figure shows the number of species of algae on two 20 x 20 cm algae survey quadrats per station.

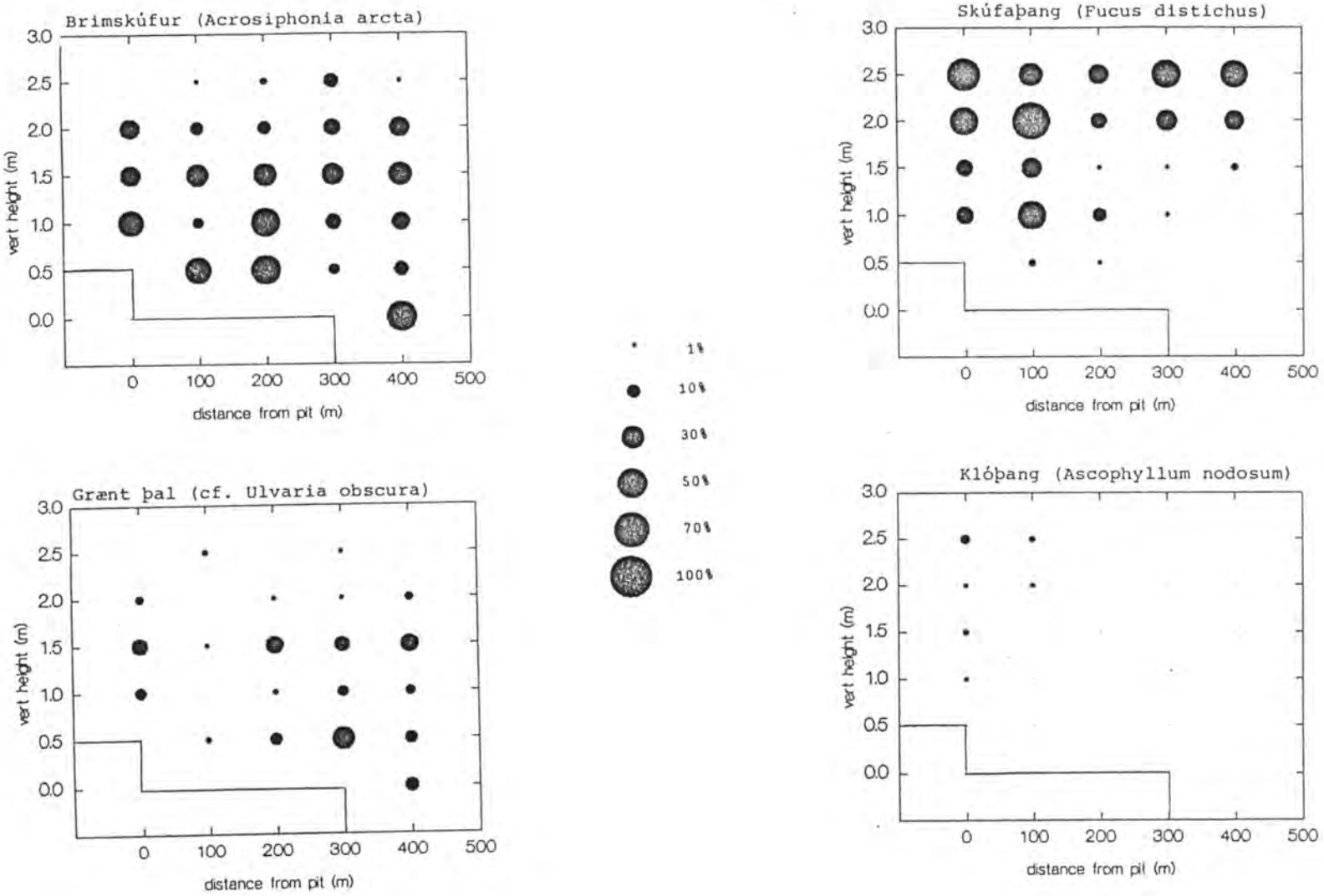


Figure 14. Cover (%) of the algae *Acrosiphonia arcta*, cf. *Ulvaria obscura*, *Fucus distichus* and *Ascophyllum nodosum* on stations in area II, Straumsvík, June 1989.

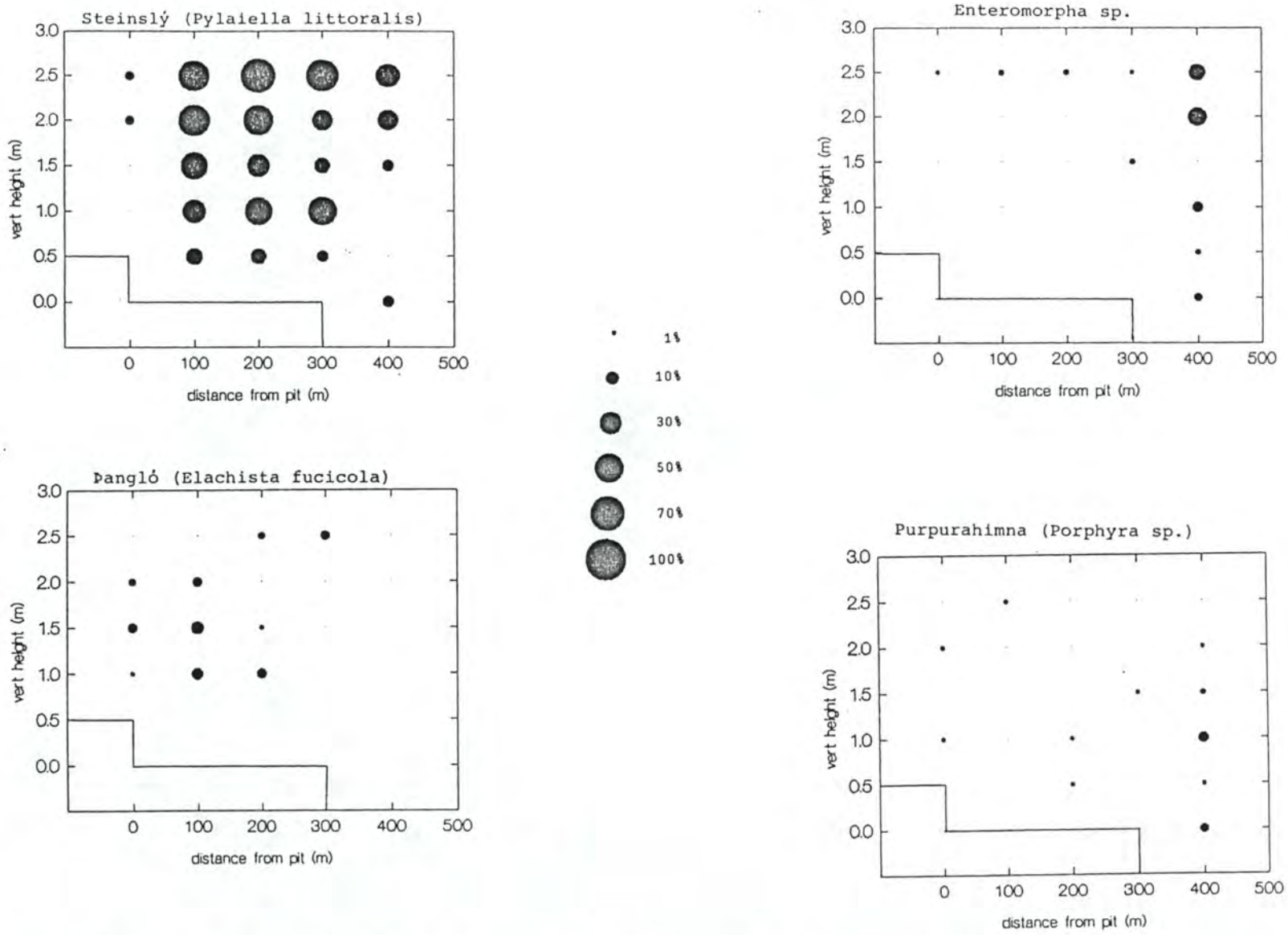


Figure 15. Cover (%) of the algae *Pylaiella littoralis*, *Elachista fucicola*, *Enteromorpha* sp. and *Porphyra* sp. on stations in area II, Straumsvík, June 1989.

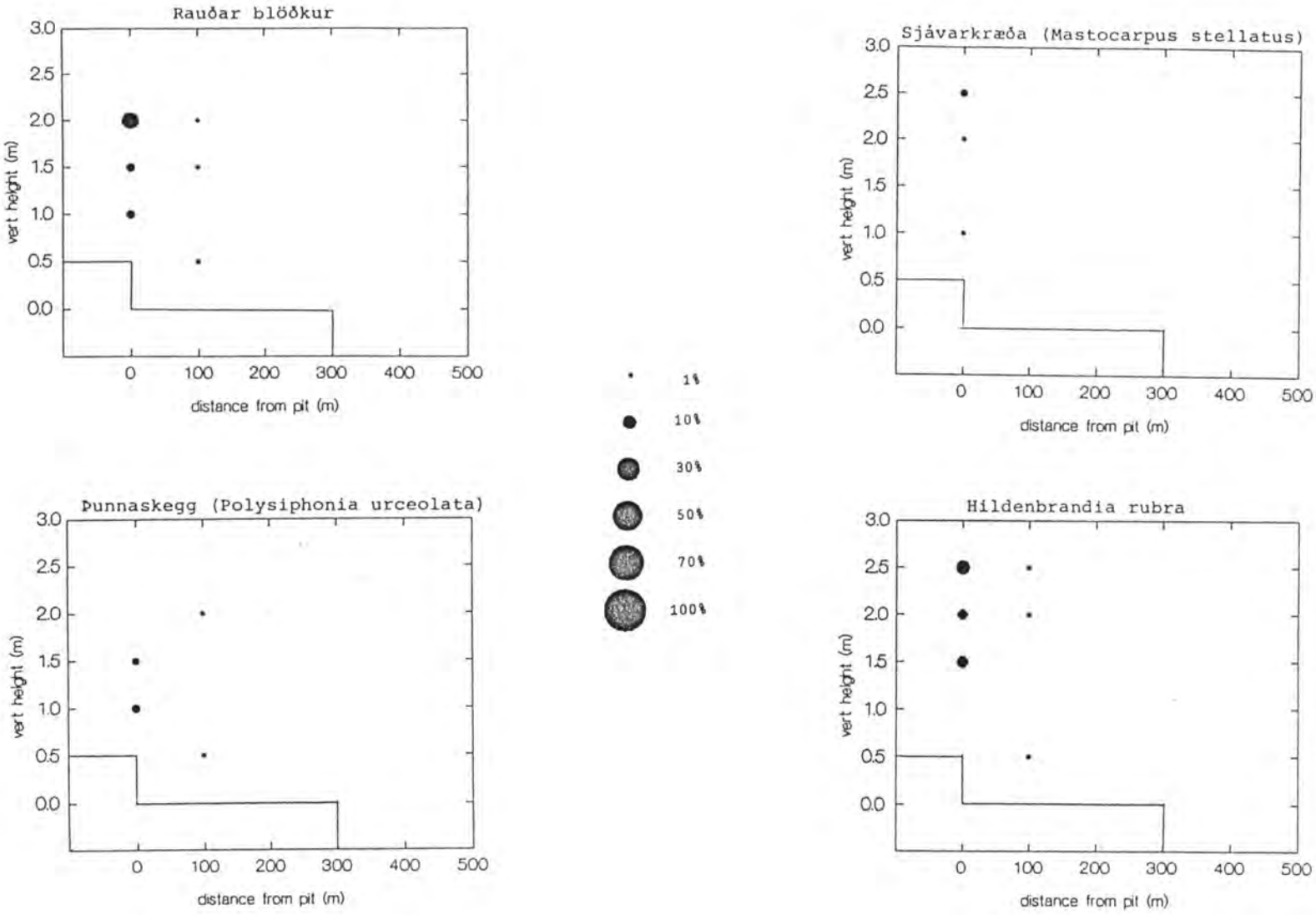


Figure 16. Cover (%) of an unidentified red membranous algae and of the algae *Polysiphonia urceolata*, *Mastocarpus stellatus* and *Hildenbrandia rubra* on stations in area II, Straumsvík, June 1989.

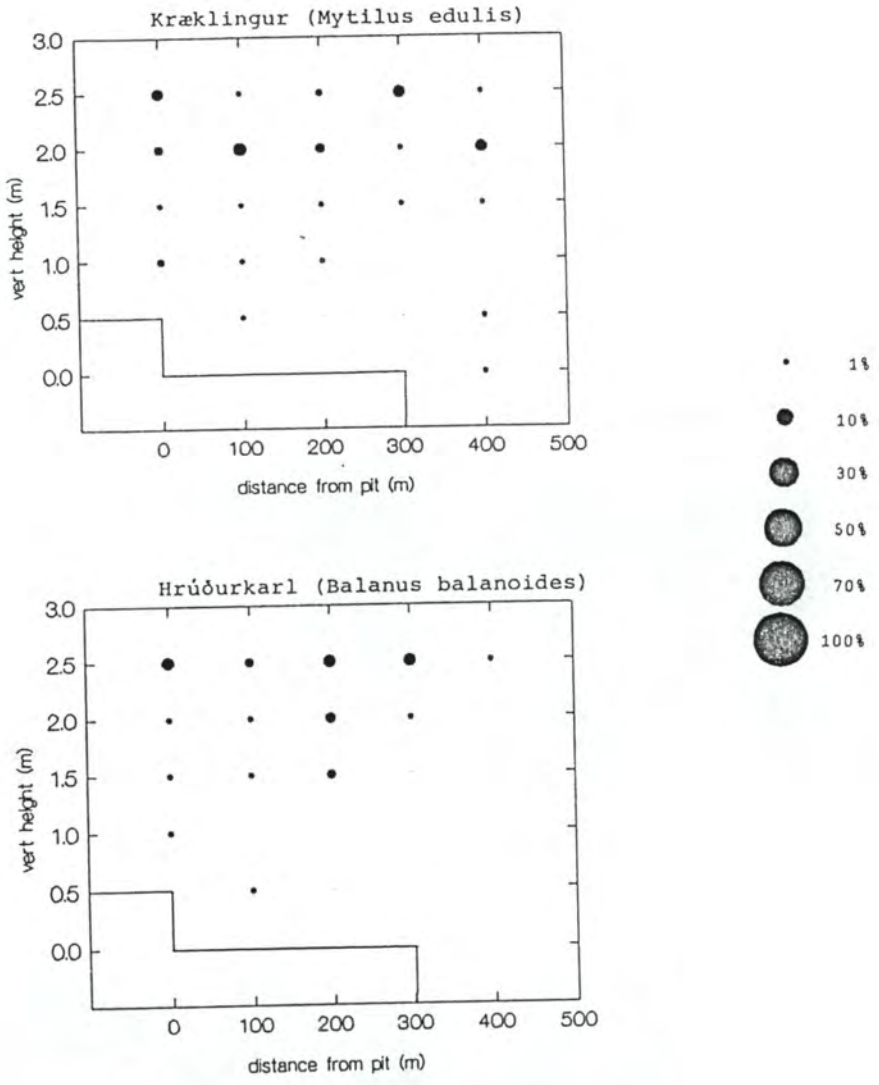


Figure 17. Cover (%) of the sessile animals *Mytilus edulis* and *Balanus balanoides* on stations in area II, Straumsvík, June 1989.

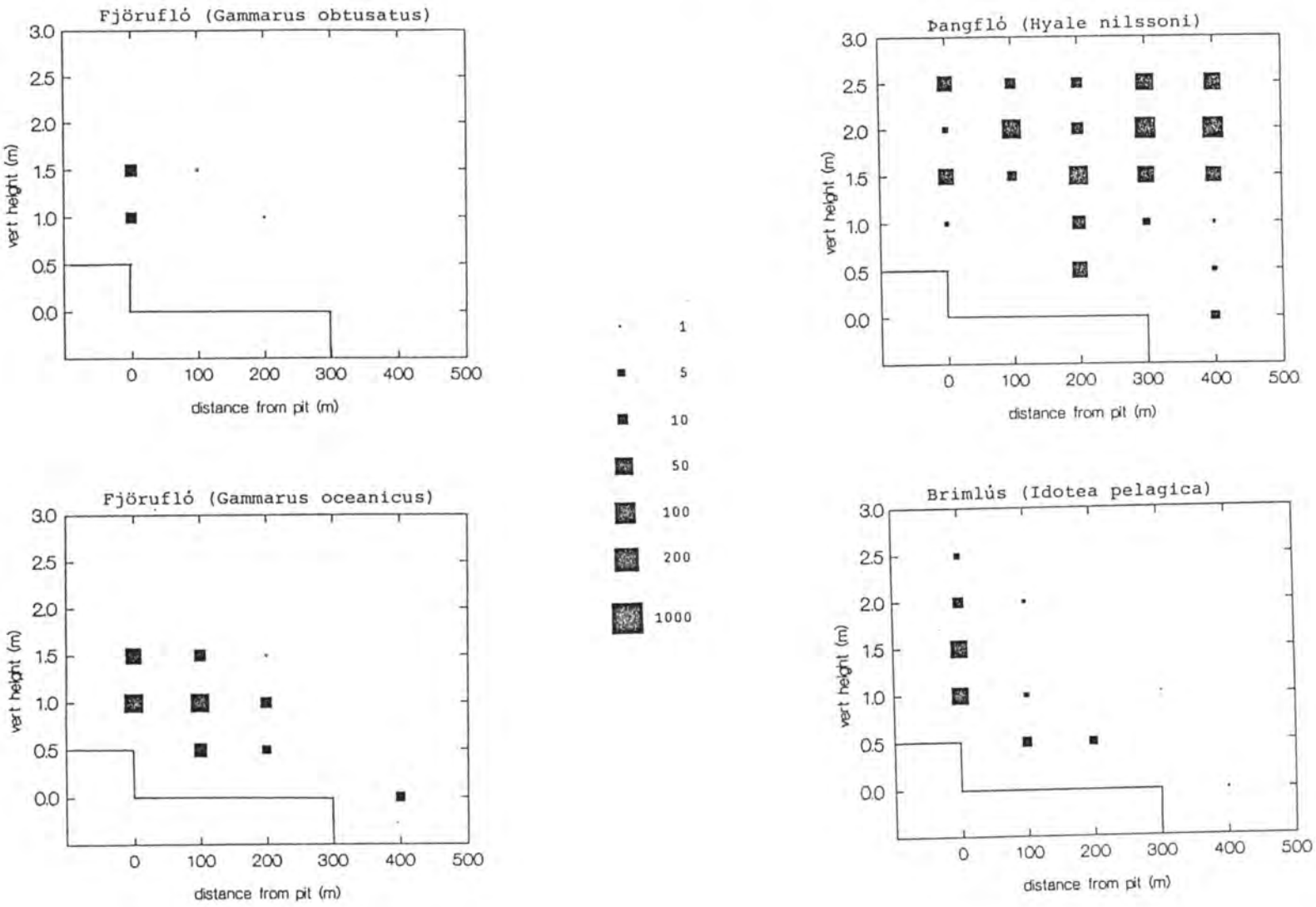


Figure 18. Number of individuals per station of the amphipods *Gammarus obtusatus*, *Gammarus oceanicus* and *Hyale nilssoni* and of the isopod *Idotea pelagica* in area II, Straumsvík, June 1989. The area investigated per station is 800 cm^2.

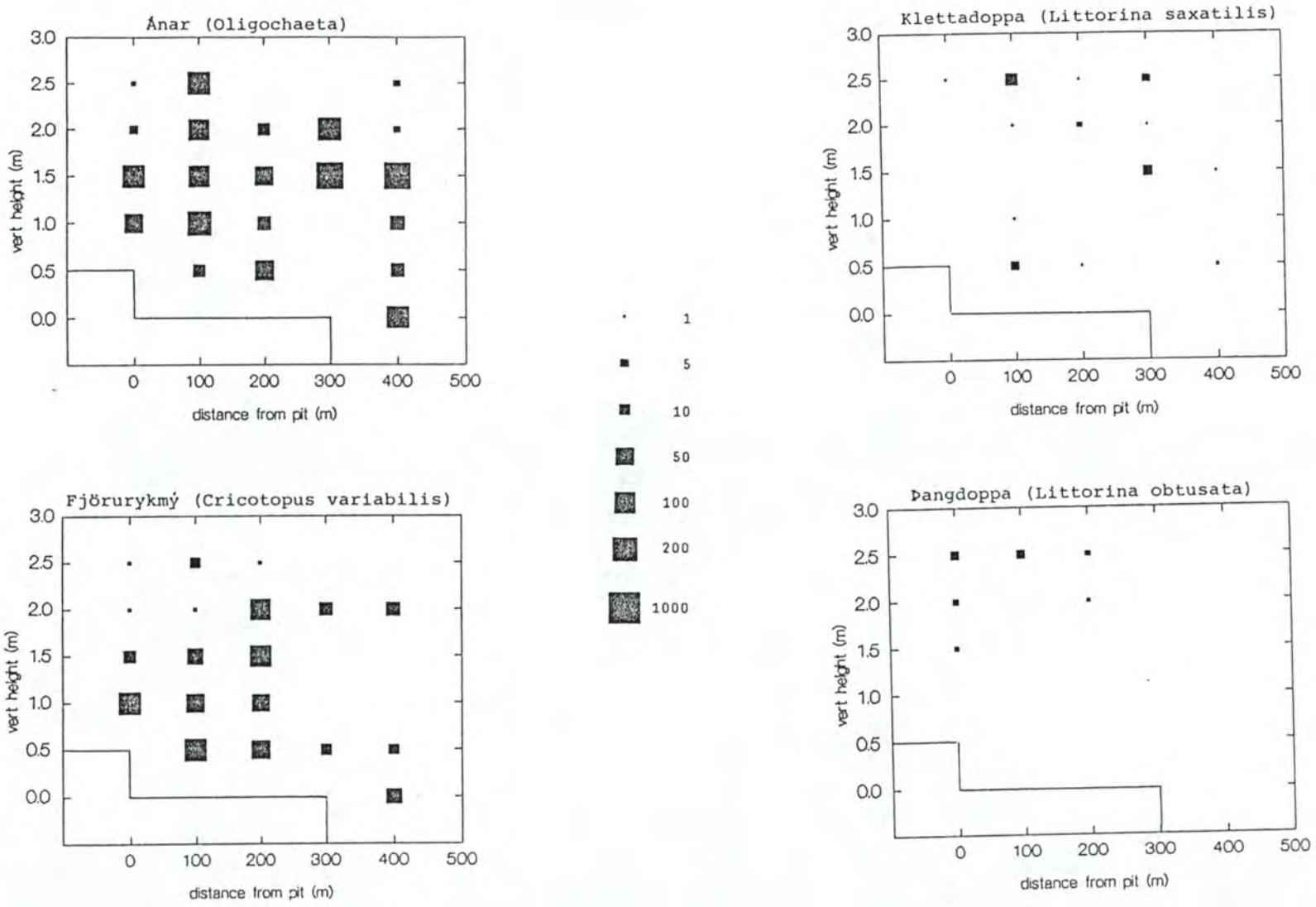


Figure 19. Number of individuals per station of oligochaetes, the chironomid *Cricotopus variabilis* and of the winkles *Littorina saxatilis* and *Littorina obtusata* in area II, Straumsvík, June 1989. The area investigated per station is 800 cm².

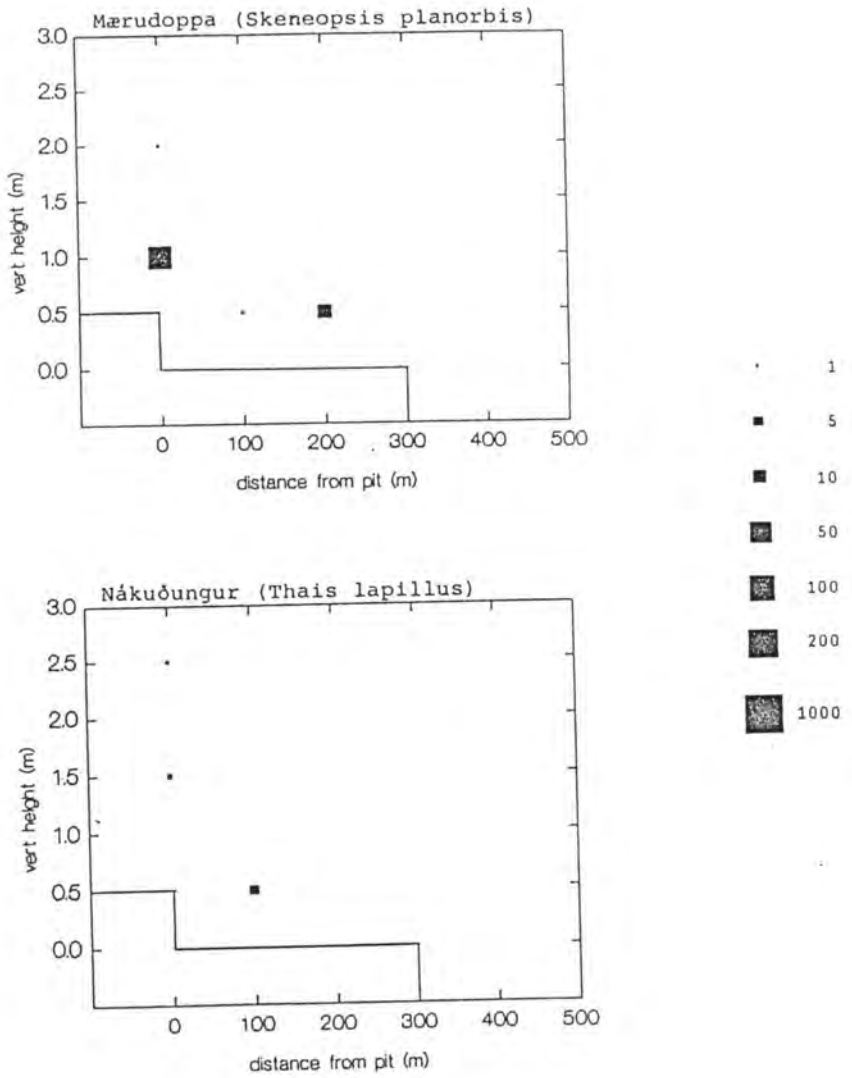


Figure 20. Number of individuals per station of the gastropods *Skeneopsis planorbis* and *Thais lapillus* in area II, Straumsvík, June 1989. The area investigated per station is 800 cm^2.

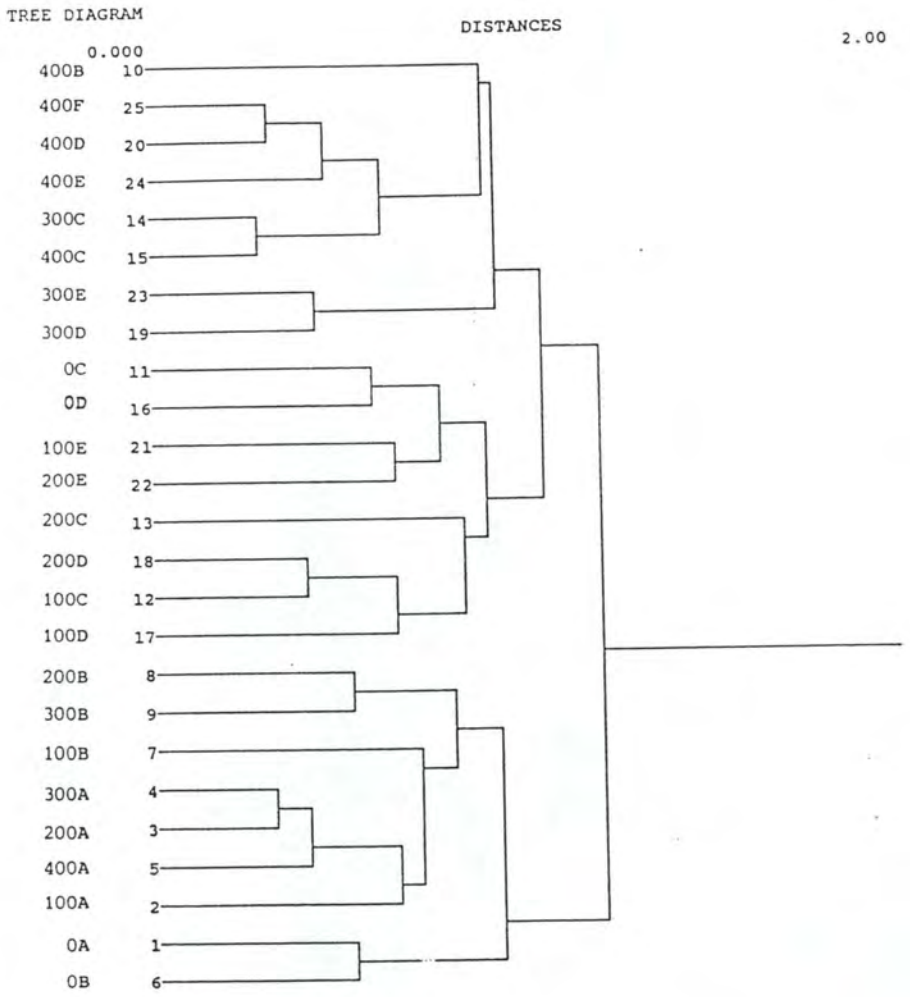


Figure 21. A dendrogram showing clustering of stations in area II, Straumsvík. Distance metric is 1-Pearson correlation coefficient and the linkage is average. Cover percentages and animal numbers have been ranked for each species before analysis.

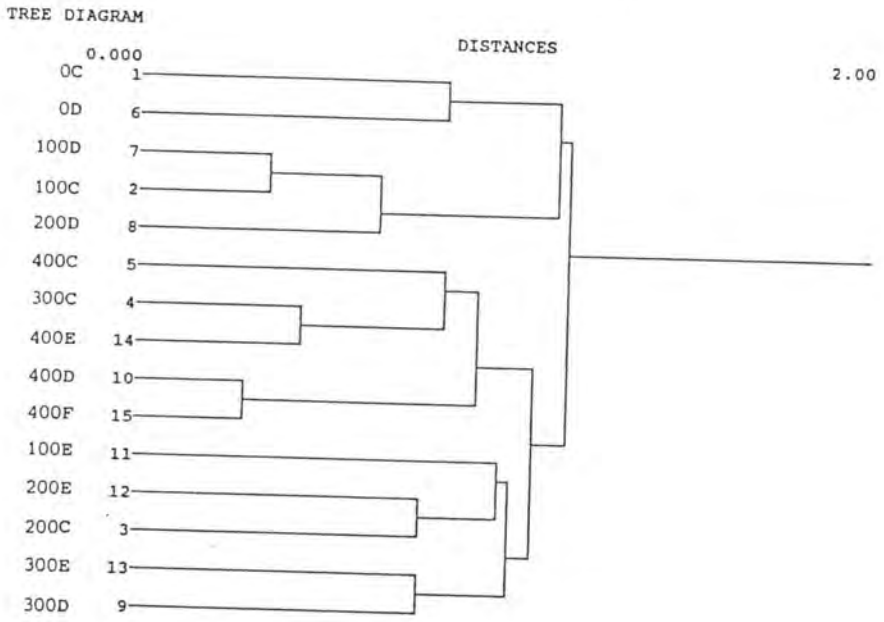


Figure 22. A dendrogram showing clustering of C-F stations in area II, Straumsvík. Distance metric is 1-Pearson correlation coefficient and the linkage is average. Cover percentages and animal numbers have been ranked for each species before analysis.

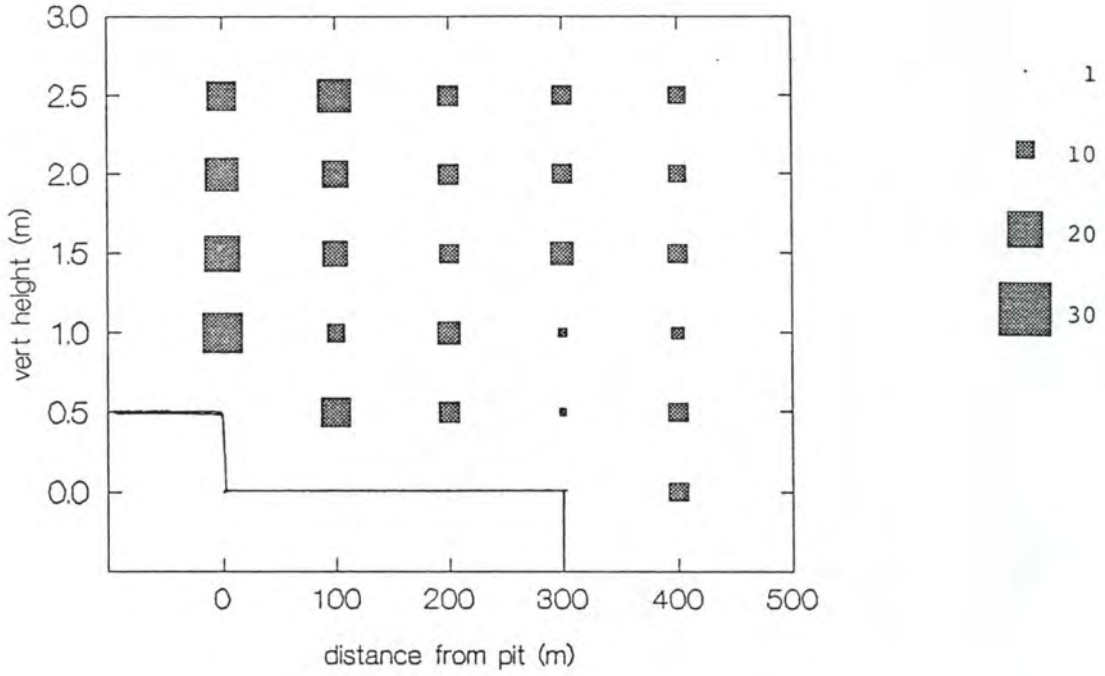


Figure 23. Number of species algae and animals per station in area II, Straumsvík, based on two 1 x 0.5 m cover quadrats and on two 20 x 20 cm animal survey quadrats per station.

Appendix A

Cover (%) of algae and sessile animals in area I, Straumsvik

Straumsvik, area I. Cover (%) of algae and sessile animals on A-stations. Height = 2.5 m.
x = cover < 1%

100 points investigated per station.

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Verrucaria maura	95	62	57	36	40	22
Pelvetia canaliculata	5	35	1	2	12	65
Fucus spiralis	8	16	45	27	40	22
Ascophyllum nodosum				6	6	
Green filaments 1)		x		28	10	
Hildenbrandia rubra			2			
Puccinellia maritima					3	

1) chiefly Rhizoclonium riparium

Straumsvik, area I. Cover (%) of algae and sessile animals on B-stations. Height = 2.0 m.
x = cover < 1%

100 points investigated per station.

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Verrucaria maura				5	3	
V. mucosa	15				4	
Fucus spiralis	31			68	37	36
Ascophyllum nodosum	69	98	86	49	84	68
Cladophora rupestris	28	47	15		2	
Hildenbrandia rubra	37	13	100	x	78	
Mytilus edulis	3	2	x	0	x	0
Balanus balanoides	x	x	1			

Straumsvik, area I. Cover (%) of algae and sessile animals on C-stations. Height = 1.5 m.
x = cover < 1%

100 points investigated per station.

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Verrucaria mucosa	x					
Fucus vesiculosus						x
Ascophyllum nodosum	97	99	100	98	97	98
Cladophora rupestris	63	81	94	42	44	5
Mastocarpus stellatus					3	
Hildenbrandia rubra	28	21	60	45	92	76
Corallinaceae	x		x		3	
Mytilus edulis	1	1	2	4	3	x
Balanus balanoides	x		x	17	x	x

Straumsvik, area I. Cover (%) of algae and sessile animals on D-stations. Height = 1.0 m.
x = cover < 1%

100 points investigated per station.

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Verrucaria mucosa				2		
Fucus vesiculosus				1		17
Ascophyllum nodosum	97	98	100	98	100	72
Elachista fucicola	6	x				
Cladophora rupestris	58	73	91	9	6	1
Ulvaria obscura [1]						4
Mastocarpus stellatus					x	
Hildenbrandia rubra	4	25	60	44	9	24
Corallinaceae	x		5			
Polysiphonia lanosa			1		x	1
Mytilis edulis	39	x	5	23	55	10
Balanus balanoides				4	5	1

1) chiefly

Straumsvik, area I. Cover (%) of algae and sessile animals on E-stations. Height = 0.5 m.
x = cover < 1%

100 points investigated per station.

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Fucus vesiculosus				64	19	10
Ascophyllum nodosum	97	99	96	31	65	88
Elachista fucicola	12	3	1	4		
Cladophora rupestris	20	47	59	4	6	x
Ulvaria obscura [1]	6	x		1		20
Mastocarpus stellatus	4	x	x		x	1
Hildenbrandia rubra		17	15	18	10	23
Corallinaceae			x			
Palmaria palmata	3					
Polysiphonia lanosa		x	12			5
Devaleraea ramentacea	1					
Mytilus edulis	9	x	1	39	77	6
Balanus balanoides				13	x	

1) chiefly

Straumsvik, area I. Cover (%) of algae and sessile animals on F-stations. Height = 0 m.
x = cover < 1%

100 points investigated per station.

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Fucus vesiculosus	1	17	3	80	49	45
Fucus distichus			23			
Ascophyllum nodosum	17	47	25	6	33	17
Elachista fucicola	2		3	6	4	x
Cladophora rupestris	1	37	20	x	5	10
Acrosiphonia arcta			7			
Enteromorpha sp. [1]					1	
Ulvaria obscura	9	17	8	34	15	49
Mastocarpus stellatus	5	10	2	x	11	5
Hildenbrandia rubra		2	15	16		2
Corallinaceae	3					
Palmaria palmata	1	x				
Polysiphonia lanosa		19	13	x	7	x
Devaleraea ramentacea	21	x	x			
Mytilus edulis	x		2	30	x	1

1) chiefly

Straumsvik, area I. Dry weight (g) of large algae. The numbers show summed weights on two 20 x 20 cm quadrats.

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
A-stations. Height =2.5 m						
Pelvetia canaliculata	4.9	14.4	0.4	2.5	3.4	31.6
Fucus spiralis	0.3	2.9	9.3	5.7	37.9	0.9
B-stations. Height=2.0 m						
Fucus spiralis	8.8		1.9	34.4	60.1	11.6
Ascophyllum nodosum	97.9	191.7	83.7	10.1	64.5	152.6
Polysiphonia lanosa						<0.1
C-stations. Height=1.5 m						
Ascophyllum nodosum	151.0	206.3	190.8	83.6	164.4	239.8
D-stations. Height=1.0 m						
Fucus vesiculosus				3.8		2.4
Ascophyllum nodosum	601.7	158.5	44.7	118.2	207.7	132.2
E-stations. Height=0.5 m						
Fucus vesiculosus				29.5	20.9	16.4
Ascophyllum nodosum	203.2	163.1	158.1	79.2	63.9	209.9
Polysiphonia lanosa		0.2	1.7			1.0
F-stations. Height=0 m						
Fucus vesiculosus	0.6	23.3		106.5	12.0	12.0
F. distichus			50.6			
Ascophyllum nodosum	89.9	65.1	105.6	2.3	106.5	54.8
Polysiphonia lanosa		8.6	8.4	0.2	8.6	0.3

Appendix C

Species of algae identified from 20 x 20 cm algae survey quadrats, area I, Straumsvík

Straumsvík, area I. Species of algae identified from 20 x 20 cm quadrats on A-stations. Height = 2.5 m. Two quadrats investigated per station.

\+ = species identified from one quadrat only
++ = species identified from both quadrats

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Rhodochorton purpureum				+		
Choreocolax polysiphoniae					+	+
Devaleraea ramentacea		+				
Palmaria palmata						+
Aglaothamnion scopulorum						+
Ceramium rubrum		++			+	+
Polysiphonia lanosa		+			+	+
Pylaiella littoralis		+				
Pelvetia canaliculata	++	++	+	++	+	++
Fucus spiralis	++	++	++	+	++	++
Cladophora rupestris		+			+	++
Rhizoclonium riparium				+		
Ulothrix sp.				+		
Acrosiphonia arcta		+				+
Spongomorpha aeruginosa		+			+	
Rosenvingiella polyrhiza				+		
Ulvaria obscura		++			+	++
Monostroma grevillei	+	++			++	++

Straumsvík, area I. Species of algae identified from 20 x 20 cm quadrats on B-stations. Height = 2.0 m. Two quadrats investigated per station.

\+ = species identified from one quadrat only
++ = species identified from both quadrats

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Kylinia secundata			+			
Rhodochorton purpureum	+					+
Ahnfeltia plicata						+
Chondrus crispus						+
Mastocarpus stellatus						+
Dumontia contorta						+
Choreocolax polysiphoniae			+			+
Palmaria palmata				+		
Aglaothamnion scopulorum			+			++
Polysiphonia lanosa		+				
Elachista fucicola		++	++	++	++	++
Ascophyllum nodosum	++		++	++	++	++
Fucus spiralis	+	++	++	++	+	++
Cladophora rupestris	++			+		
Pseudopringsheimia fucicola		+		+	++	++
Ulvaria obscura		+			++	+
Monostroma grevillei	+					
M. undulatum	+					

Straumsvik, area I. Species of algae identified from 20 x 20 cm quadrats on C-stations. Height = 1.5 m. Two quadrats investigated per station.

\+ = species identified from one quadrat only
++ = species identified from both quadrats

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Kylinia secundata	+		+			+
Cystoclonium purpueum						+
Mastocarpus stellatus						+
Palmaria palmata						++
Ceramium rubrum		+			+	+
Polysiphonia lanosa		+				
Ascophyllum nodosum	++	++	++	++	++	++
Cladophora rupestris	++	++	++	++	++	++
Acrosiphonia arcta		+			+	
Ulvaria obscura	+	+	++		++	++
Monostroma grevillei	+	++			++	++
M. undulatum					+	

Straumsvik, area I. Species of algae identified from 20 x 20 cm quadrats on D-stations. Height = 1.0 m. Two quadrats investigated per station.

\+ = species identified from one quadrat only
++ = species identified from both quadrats

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Kylinia secundata		+				
K. virgatula		+				
Chondrus crispus						+
Mastocarpus stellatus					+	
Palmaria palmata		+	+			+
Ceramium rubrum		++	+			
Plumaria elegans			+			
Polysiphonia lanosa	+					
P. urceolata	+					
Elachista fucicola	++					
Pylaiella littoralis		+				+
Ascophyllum nodosum	++	++	++	++	++	++
Fucus vesiculosus				++		+
Cladophora rupestris	++	++	++	+	++	++
Acrosiphonia arcta		+				+
Enteromorpha		+				
Ulva lactuca		+				
Ulvaria obscura	++	++				+
Monostroma grevillei	+	+		+	++	
M. undulatum		+		+		
Ectocarpus		+				

Straumsvik, area I. Species of algae identified from 20 x 20 cm quadrats on E-stations. Height = 0.5 m. Two quadrats investigated per station.

\+ = species identified from one quadrat only
++ = species identified from both quadrats

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Kylinia secundata	+			+		
Rhodochorton purpureum	+		+			
Chondrus crispus	+					
Mastocarpus stellatus	++	+	+	+		+
Choreocolax polysiphoniae	+		++	+		+
Devaleraea ramentaceum	++			+		
Palmaria palmata	++	++	+	+		++
Aglaothamnion scopulorum				+		
Antithamnion floccosum	++					
Ceramium rubrum	+	++		+		+
C. deslongchampsii		+				
Polysiphonia lanosa	+	+	++	+		++
P. urceolata						+
Elachista fucicola	+		++	++		+
Isthmoplea spherophora						+
Pylaiella littoralis			+	+		++
Ascophyllum nodosum	++	++	++	++	++	++
Fucus vesiculosus				+	++	++
Chaetomorpha capillaris	++	+	+			
Cladophora rupestris	++	++	++	++		+
Acrosiphonia arcta						+
Spongomorpha aeruginosa				+		
Pseudopringsheimia fucicola			++	+		
Ulva lactuca						+
Ulvaria obscura	++	+	++	++	++	++
Monostroma grevillei	++	++	+	+	+	+
M. undulatum						+

Straumsvik, area I. Species of algae identified from 20 x 20 cm quadrats on F-stations. Height = 0 m. Two quadrats investigated per station.

\+ = species identified from one quadrat only
++ = species identified from both quadrats

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Kylinia secundata	+		+	+		+
K. virgatula		+	+			
Rhodochorton purpureum	++	+	+			+
Chondrus crispus		+				
Mastocarpus stellatus	++	++	+	+	++	+
Choreocolax polysiphoniae	+	++	+		++	
Devaleraea ramentacea	++	++				++
Palmaria palmata	++	++	++		+	++
Aglaothamnion scopulorum			+			
Antithamnion floccosum	+					
Ceramium rubrum	+	+		+		
C. arborescens		++	+			
C. deslongchampsii	++					+
Plumaria elegans	+					
Ptilota plumosa	+					
Polysiphonia lanosa	++	++	++	+	++	+
P. urceolata	++	+			+	+
Porphyra sp.	+					
Elachista fucicola	++	+	+	++	+	
Isthmoplea sphaerophora						++
Pylaiella littoralis	+		+		+	++
Sphacelaria radicans	++					+
Ascophyllum nodosum,	++	++	++	+	++	+
Fucus vesiculosus	+	++		++	++	+
F. distichus			+			
Chaetomorpha capillaris	+	++		+	++	++
Cladophora rupestris	++	++	++		++	++
Ulothrix sp.	++	+				
Acrosiphonia arcta	++	++		++	+	++
Spongomorpha aeruginosa	+	+	+			
Pseudopringsheimia fucicola	++	+	+			
Enteromorpha					+	+
Ulvaria obscura	++	++	++	++	++	++
Monostroma grevillei	++	++	++	++	++	++
M. undulatum	+					

Appendix D

Counts of animals from 20 x 20 cm animal survey quadrats, area I, Straumsvík

Straumsvik, area I. Counts of animals in 20 x 20 cm quadrats on A-stations. Height = 2.5 m.

	Total number of animals on two 400 cm^2 quadrats					
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Littorina saxatilis	1	14	6	0	4	65
Micralymma marinum						1
Hyale nilssoni	1					

Straumsvik, area I. Counts of animals in 20 x 20 cm quadrats on B-stations. Height = 2.0 m.

	Total number of animals on two 400 cm^2 quadrats					
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Dynamena pumila	x	x				
Littorina saxatilis	1	11	1	0	9	14
L.obtusata	3	6	0	0	2	3
Micralymma marinum				1	1	3
Jaera spp.	18	10	28	0	39	179
Hyale nilssoni	70	19	31	2	69	30
Gammarus marinus						1
Oligochaeta	52					1

Straumsvik, area I. Counts of animals in 20 x 20 cm quadrats on C-stations. Height = 1.5 m.

	Total number of animals on two 400 cm^2 quadrats					
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Littorina saxatilis	5	5	1	16	5	3
L.obtusata	28	2	0	1	0	0
Oligochaeta		2				
Micralymma marinum			2		1	
Idotea granulosa	7					
Jaera spp.	8	20	15	0	13	16
Hyale nilssoni	75	27	41	0	26	13

Straumsvik, area I. Counts of animals in 20 x 20 cm quadrats on D-stations. Height = 1.0 m.

	Total number of animals on two 400 cm^2 quadrats					
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Littorina saxatilis	11	0	0	36	17	40
L.obtusata	20	5	4	8	17	3
Onoba aculeus	1					
Skeneopsis planorbis		16				
Cyamium minutum		1				
Fabricia sabella		x				
Oligochaeta	27	2				
Cricotopus variabilis	1	0	0	0	0	0
Micralymma marinum	4	1	1			
Idotea granulosa	1	0	2	0	0	0
Jaera spp.	9	5	3	14	5	25
Hyale nilssoni	38	60	69	30	15	22
Gammarus occanicus				2		1
G. obtusatus	28		1	7	1	6

Straumsvik, area I. Counts of animals in 20 x 20 cm quadrats in E-stations. Height = 0.5 m.

	Total number of animals on two 400 cm^2 quadrats					
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Littorina saxatilis	6	8	1	81	104	30
L.obtusata	11	52	9	5	38	34
Lacuna vincta						1
Onoba aculeus					1	
Skeneopsis planorbis						1
Thais lapillus	6	4	3		2	
Fabricia sabella	x	x				
Oligochaeta	76	104	18		4	
Cricotopus variabilis	29	1	1	37	1	4
Micralymma marinum	2		8	1		
Idotea granulosa	3	6	2	0	0	0
Jaera spp.	1	0	0	49	81	65
Hyale nilssoni	8	6	9	13	77	17
Gammarus occanicus				4	21	11
G. obtusatus			1	2	37	37

Straumsvik, area I. Counts of animals in 20 x 20 cm quadrats in F-stations. Height = 0 m.

	Total number of animals on two 400 cm^2 quadrats					
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400	Trans 500
Littorina saxatilis	8	18	4	132	10	34
L.obtusata	19	52	61	98	30	45
Onoba aculeus			3			
Skeneopsis planorbis			1			41
Thais lapillus	10	24	15	2	20	2
Cyamium minutum						10
Fabricia sabella	x					
Oligochaeta	1703	422	279			40
Cricotopus variabilis	640	21	15	21	1	4
Micralymma marinum	1					1
Idotea granulosa	4	5	5	0	0	0
Jaera spp.	4	3	16	11	0	2
Hyale nilssoni	3	18	4	8	0	5
Gammarus occanicus		3		27	3	12
G. obtusatus	5	8	2	12	0	5
Amphithoe rubricata			1			

Appendix E

Cover (%) of algae and sessile animals in area II, Straumsvík

Straumsvik, area II. Cover (%) of algae and sessile animals on A-stations. Height = 2.5 m. x = < 1 % cover.

100 points investigated per station

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400
Verrucaria mucosa	x				
Fucus vesiculosus		8			
F. distichus	63	32	23	47	44
Ascophyllum nodosum	5	2			
Elachista fucicola			3	5	
Pylaiella littoralis	5	59	75	65	35
Acrosiphonia arcta		x	3	12	x
Enteromorpha sp.	x	x	x	1	17
cf. Ulvaria obscura		2		x	
Mastocarpus stellatus	3				
Porphyra sp.		x			
Hildenbrandia rubra	11	x			
Mytilus edulis	5	x	2	6	1
Balanus balanoides	6	3	6	6	x
Dynamena pumila	1				

Straumsvik, area II. Cover (%) of algae and sessile animals on B-stations. Height = 2.0 m. x = < 1 % cover.

100 points investigated per station

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400
Fucus distichus	47	81	15	26	23
Ascophyllum nodosum	1	x			
Elachista fucicola	3	5			
Pylaiella littoralis	10	61	56	26	25
Acrosiphonia arcta	22	10	10	16	23
Enteromorpha sp.					22
cf. Ulvaria obscura	4		1	1	4
Mastocarpus stellatus	x				
Polysiphonia urceolata		x			
Porphyra sp.	1				x
Unident. red membrane	16	x			
Hildenbrandia rubra	6	1			
Mytilus edulis	3	7	4	x	6
Balanus balanoides	1	1	4	x	

Straumsvik, area II. Cover (%) of algae and sessile animals on C-stations. Height = 1.5 m. x = < 1 % cover.

100 points investigated per station

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400
Fucus distichus	16	23	x	x	3
Ascophyllum nodosum	2				
Elachista fucicola	5	9	x		
Pylaiella littoralis		44	32	22	8
Petalonia sp.				x	
Acrosiphonia arcta	23	29	30	27	31
Enteromorpha sp.				2	
cf. Ulvaria obscura	15	1	17	13	18
Polysiphonia urceolata	3				
Porphyra sp.				1	2
Hildenbrandia rubra	8				
Unident. red membrane	4	x			
Mytilus edulis	x	x	x	x	x
Balanus balanoides	x	x	3		

Straumsvik, area II. Cover (%) of algae and sessile animals on D-stations. Height = 1.0 m. x = < 1 % cover.

100 points investigated per station

	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400
Fucus distichus	17	45	11	x	
Ascophyllum nodosum	x				
Elachista fucicola	x	8	6		
Pylaiella littoralis		34	48	51	
Acrosiphonia arcta	37	7	47	14	19
Enteromorpha sp.					7
cf. Ulvaria obscura	8		2	7	6
Mastocarpus stellatus	x				
Polysiphonia urceolata	4				
Porphyra sp.	x		1		7
Ceramium rubrum	x				
Unident. red membrane	4				
Unident. algae	1				
Mytilus edulis	2	x	x		
Balanus balanoides	x				

Straumsvik, area II. Cover (%) of algae and sessile animals on E-stations. Height = 0.5 m. x = < 1 % cover.

100 points investigated per station

	Trans 100	Trans 200	Trans 300	Trans 400
Fucus distichus	3	x		
Pylaiella littoralis	17	15	8	
Acrosiphonia arcta	41	49	7	12
Enteromorpha sp.				x
cf. Ulvaria obscura	2	9	29	9
Polysiphonia urceolata	1			
Porphyra sp.		1		1
Unident. red membrane	x			
Hildenbrandia rubra	1			
Mytilus edulis	x			x
Balanus balanoides	x			

Straumsvik, area II. Cover (%) of algae and sessile animals on F-stations. Heigth = 0 m. x = < 1 % cover.

100 points investigated per station

	Trans 400
Pylaiella littoralis	8
Acrosiphonia arcta	51
Enteromorpha sp.	4
cf. Ulvaria obscura	11
Porphyra sp.	5
Mytilus edulis	x

Counts of animals from 20 x 20 cm animal survey quadrats, area II, Straumsvik

Straumsvik, area II. Counts of animals in 20 x 20 cm quadrats on A-stations. Height = 2.5 m.

	Total number of animals on two 400 m^2 quadrats				
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400
Littorina saxatilis	1	15	1	5	
L. obtusata	6	6	3		
Thais lapillus	1				
Oligochaeta	3	168			4
Cricotopus variabilis	2	10	2		1
Micralymma marinum	1	1			
Idotea granulosa		1		11	
I. pelagica	4				
Hyale nilssoni	32	12	11	51	44

Straumsvik, area II. Counts of animals in 20 x 20 cm quadrats on B-stations. Height = 2.0 m.

	Total number of animals on two 400 m^2 quadrats				
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400
Littorina saxatilis		1	3	1	
L. obtusata	4		2		
Skeneopsis planorbis	1				
Oligochaeta	6	116	15	171	4
Cricotopus variabilis	2	2	100	17	20
Idotea pelagica	12	2			
Jaera sp.			1	1	
Hyale nilssoni	4	71	14	105	103

Straumsvik, area II. Counts of animals in 20 x 20 cm quadrats on C-stations. Height = 1.5 m.

	Total number of animals on two 400 m^2 quadrats				
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400
Littorina saxatilis				8	1
L. obtusata	3				
Thais lapillus	2				
Oligochaeta	133	109	62	371	314
Cricotopus variabilis	15	35	123	32	1
Acarina		4			
Idotea pelagica	42				
Jaera sp.					1
Hyale nilssoni	37	9	70	39	59
Gammarus oceanicus	37	13	1		
G. obtusatus	17	1			
Parajassa pelagica	2				
Nematoda	32				

Straumsvík, area II. Counts of animals in 20 x 20 cm quadrats on D-stations. Height = 1.0 m.

	Total number of animals on two 400 m^2 quadrats				
	Trans 0	Trans 100	Trans 200	Trans 300	Trans 400
Littorina saxatilis		1			
Skeneopsis planorbis	65				
Fabricia sabella	x				
Oligochaeta	56	220	20		22
Cricotopus variabilis	163	64	50	1	1
Idotea pelagica	49	3			
Jaera sp.			1		
Hyale nilssoni	3		19	5	2
Gammarus oceanicus	64	60	11		
G. obtusatus	12		1		
Nemertea	1				
Nematoda	5				

Straumsvík, area II. Counts of animals in 20 x 20 cm quadrats on E-stations. Height = 0.5 m.

	Total number of animals on two 400 m^2 quadrats			
	Trans 100	Trans 200	Trans 300	Trans 400
Littorina saxatilis	6	1		2
Skeneopsis planorbis	1	12		
Thais lapillus	5			
Oligochaeta	14	75		18
Cricotopus variabilis	147	68	10	9
Idotea granulosa	4			
I. pelagica	9	6		
Hyale nilssoni		33		3
Gammarus oceanicus	18	7		

Straumsvík, area II. Counts of animals in 20 x 20 cm quadrats on F-stations. Height = 0 m.

	Total number of animals on two 400 m^2 quadrats
	Trans 400
Oligochaeta	116
Cricotopus variabilis	28
Idotea pelagica	1
Hyale nilssoni	7
Gammarus oceanicus	8
Amphithoe rubricata	2