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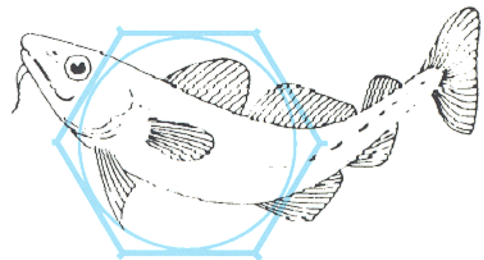

Environmental Impact of Marine Colliery Waste Disposal Operations on the Sea Bed off Seaham, County Durham

D.S. Limpenny, S.M. Rowlatt and P.M. Manning

MAFF
Directorate of Fisheries Research
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MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
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LOWESTOFT
1992

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1. INTRODUCTION

Waste materials from coal mining and harbour dredging are discharged to the marine environment off Seaham.

Mining activities produce wastes of two types:

- minestone, which consists mainly of sandstones and shales (generally coarser than 0.5 mm) from which the coal has been separated by a water-based gravity process; and
- tailings, which form the fine fractions of the waste separated from the coal by an oil/water flotation process and which have a particle size of less than 0.5 mm.

The discharge of colliery tailings onto the beach via two separate pipes, under a consent issued by the National Rivers Authority, contributes approximately 1.0 x 10^6 tonnes dry weight per annum to the marine environment. Approximately 1.2 x 10^6 tonnes per annum of minestone is deposited directly onto the beach, from whence it is dispersed by wave action. Disposal of minestone is licensed by MAFF under powers contained in Part II of the Food and Environment Protection Act 1985 (Great Britain — Parliament, 1985).

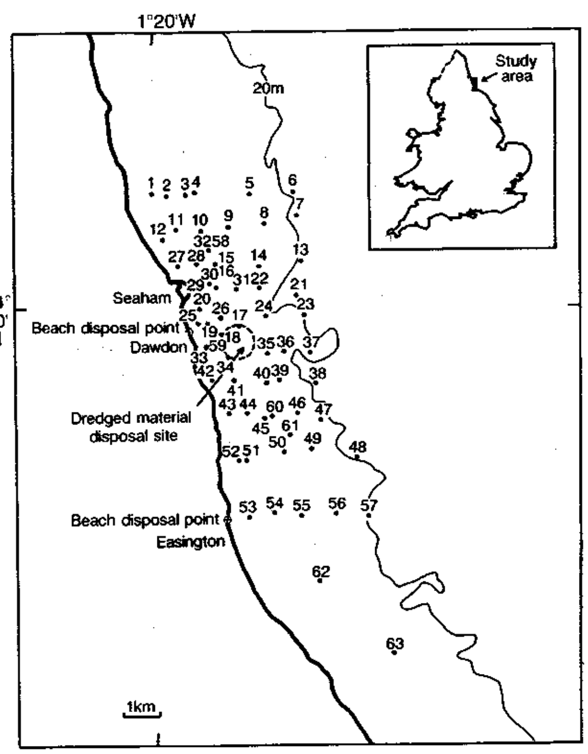

Figure 1. Stations sampled on the 1989 diver survey off the Durham coast

Each year, approximately 50 000 tonnes of dredged material from Seaham harbour are licensed for disposal at a designated disposal site 1 km east of the Dawdon beach minestone disposal site.

In 1989, MAFF carried out an intensive diver survey at 63 sampling sites off the Durham coast (Figure 1) which was designed to assess the near-field impact of colliery waste disposal on the local crab and lobster holding ground, but which also examined the effects of local dredged material disposal operations.

2. METHODS

2.1 Fieldwork

Due to the rocky nature of the sea bed over much of the area, it was not possible to carry out a sediment survey using conventional grabbing and coring equipment. Therefore, the work was carried out by the MAFF diving team operating from a local fishing vessel *DANGARRAND*. A variety of techniques were used in the field to record the nature of sea bed:

(i) A detailed description of the divers' observations was made immediately after each dive. These observations included the physical nature of the sea bed, the depth of any mud layer, evidence of sediment transport features (ripples, sand waves, etc.), the presence or absence of coal particles and details of any fauna and flora present. Divers made a special note of the presence of colliery waste over areas of the sea bed likely to provide habitats for crabs and lobsters.

(ii) A representative surface sediment sample was collected from each sampling site and stored in a plastic pot.

(iii) Still photographs of the sea bed were taken at seventeen of the sites (examples are shown in Figure 2(a-c)), and video recordings were made at a further thirty locations.

(iv) Sediment cores were taken at three sites.

(v) Samples of dredged material from Seaham harbour were collected from the disposal vessel for comparison with the survey samples. Samples of colliery tailings and minestone collected prior to this survey were also used for comparison.

Figure 2(a). The surface of the fluid mud layer at station 31

Figure 2(b). Rocky substrate with a veneer of mud south of Seaham at station 47

Figure 2(c). Rocky substrate typical of that found north of Seaham at station 7

2.2 Laboratory analysis

Several techniques were applied to the sediments to gain a comprehensive knowledge of their physical and chemical nature.

2.2.1 Trace metals

Whole (unsieved) sediments were digested in *aqua regia* and the concentrations of trace metals (Pb, Cu, Cr, Zn, Ni, Hg, Cd) were determined using atomic absorption spectrophotometry (Harper *et al.*, 1989).

2.2.2 Organic carbon

Analysis was carried out on whole (unsieved) sediments using a Perkin Elmer 240 CHN analyser after treatment with sulphurous acid to remove carbonates (Shaw, 1959).

2.2.3 Weight loss on ignition (LOI) of the 63 µm-4 mm fractions

Samples were dried in an oven at 120°C. The combustible fraction was then removed by heating at 550°C in a muffle furnace.

2.2.4 Particle size analysis

Samples were wet sieved at 63 µm to determine the fines contents. The > 63 µm fraction was then dry sieved through a series of sieves at 1/2 phi intervals (22.4 mm - 63 µm).

2.2.5 Microscopic analysis

With the aid of a light microscope, a visual description was made of the 63 µm-4 mm fraction from each sample. Amongst other things, the quantity of brick particles, as an indicator of dredged material, was noted. This was quantified by counting the number of fragments present on the surface of the sediment when observed under a pre-determined field of view. Three measurements were averaged to obtain a representative value for each sample.

2.2.6 Core samples

Cores were partially dried and sliced vertically to reveal their internal structure.

2.2.7 Total hydrocarbon content of fish and shellfish

Samples of fish and shellfish collected off Seaham in 1986 were analysed for total hydrocarbon content by the method of Law *et al.*, (1988).

3. RESULTS

3.1 Diver observations

Figure 3 shows the distribution of the three main sediment types described by the divers. The inshore part of the grid was dominated by sandy substrates, with the exception of a small region of coarser sediments 0.5 - 1 km south of Seaham. Rocky and stony substrates predominated offshore. A layer of mud, ranging from 1 cm - 1 m thick, was present over the central and central southern part of the grid (Figure 2(a)). The mud was soft enough to allow the diver to push his hand through and, in all cases but one, to identify the nature of the underlying sediment. In all cases, except that of station 33, the underlying sediment consisted of a hard-packed sand. At station 33, the mud was too thick for the diver to reach the underlying sediment. However, a core sample, collected within 100 m of this site, consisted of mud over sand. Therefore, it is likely that station 33 possesses a substrate similar to that of the other stations. At the edges of the muddy area, the fine material was intermixed with sandy sediments (Figure 4).

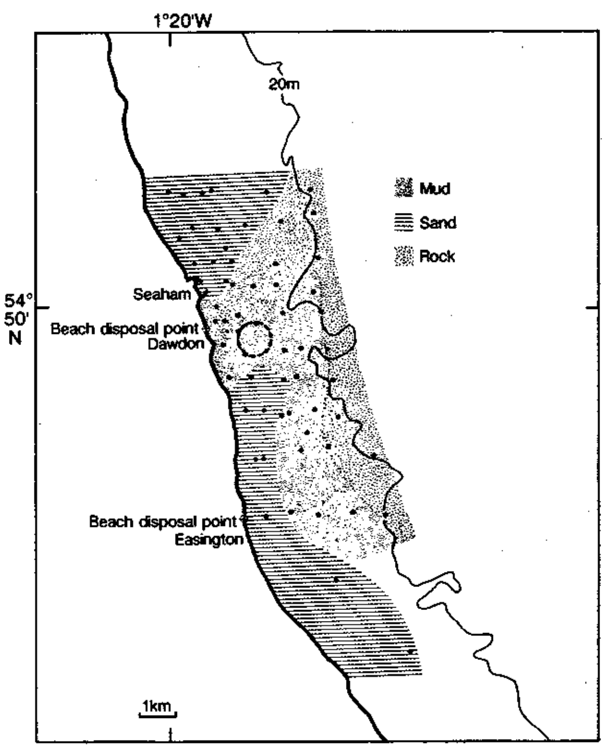

Figure 3. Major substrate types (from diver observations)

Fine material also occurred at some rocky sites in the southern half of the grid. At these sites, it appeared as a thin veneer over the rocks and as thin patches between them (Figure 2(b)). Only at station 30 could divers observe the infilling of crevices between rocks with mud. Muddy sediments were less evident north of Seaham and the rocky sites contained very little fine material (Figure 2(c)). Mud did not bury rocky substrate at any of the sites. Coal particles were observed only at 3 of the 63 sites examined, and of these only one (station 43) could be said to contain a significant quantity of coal. Coal particles were not observed to be infilling rock crevices at any of the sites.

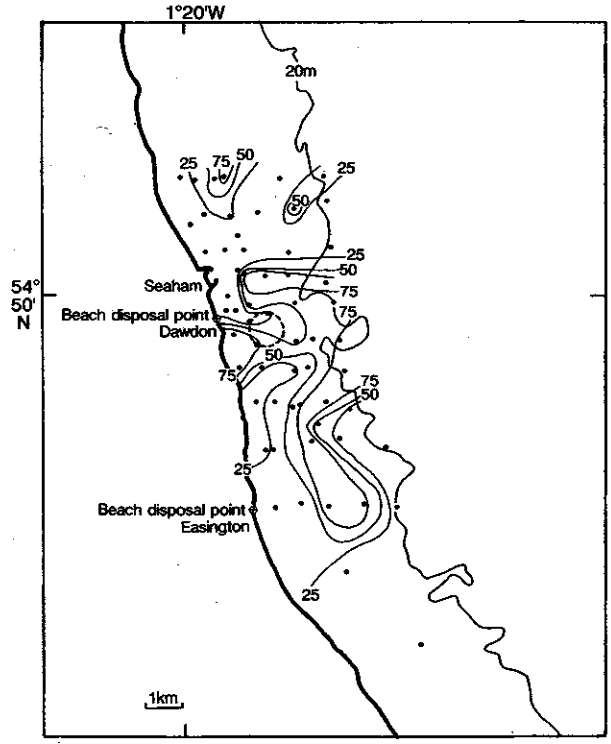

Figure 4. The percentage of fines in the surface sediment (< 63 μm)

3.2 Coal content

Residual coal is present in significant quantities in both minestone and tailings (Table 1). Previous surveys by MAFF along the north-east coast (Eagle *et al.*, 1979) used weight LOI in the sand fraction as an indicator of coal content and demonstrated the relatively high levels of coal around the beach disposal site at Seaham (Figure 5). For the purpose of comparison with the earlier data, the present samples were analysed in the same way. In addition, organic carbon values were determined instrumentally.

The present survey looks in detail at the inshore part of the impacted area identified by Eagle *et al.* (1979). Sediment-coal content is at its highest in the inshore region south of Seaham, adjacent to the beach disposal operations where values in excess of 50% coal, as determined by LOI, were recorded (Figure 6). Another area with high levels of sediment-coal appears offshore and to the south-east of the dredged material disposal site. North of Seaham, sediment-coal content is very low with much of the area exhibiting values of less than 5%. A rapid decline in coal also occurs towards the extreme south of the survey area. These results confirm the

Table 1. Metal concentrations (mg kg^{-1} dry) and coal content in colliery waste and dredged material

	Sample number	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Weight loss on ignition (%)	Organic carbon (%)
Tailings	1	0.79	29	30	0.05	38	52	54	25	13
Tailings	2	0.72	18	50	0.10	40	72	68	69	41
Minestone		-	-	-	-	-	-	-	20	13
Dredged material	1	0.22	24	36	0.21	17	61	100		
Dredged material	2	0.23	27	28	0.12	18	41	90		
Dredged material	3	0.21	23	46	0.49	19	110	210		
Dredged material	4	0.14	25	39	0.32	19	75	110		
Dredged material	5	<	23	22	0.10	16	33	60		
Dredged material	6	-	-	-	-	-	-	-	26	15

< Level below detection limit of the method used (0.1mg kg^{-1})

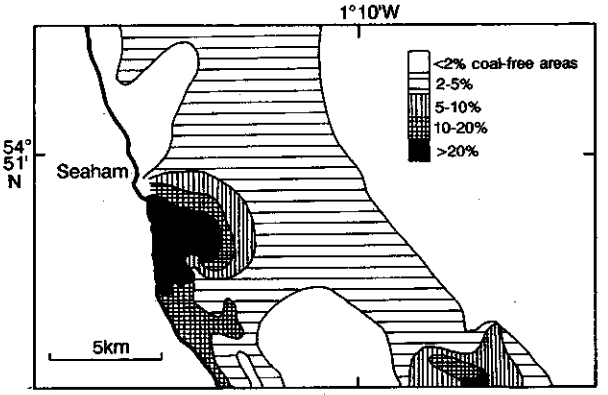

Figure 5. The percentage loss on ignition of the sand fraction in 1975-77 (Eagle et al., 1979)

spatial distribution of sediment-coal detailed by Eagle *et al.* (1979). Organic carbon concentrations follow a similar pattern to those described above and so confirm the sediment-coal distribution based on LOI results (Figure 7).

3.3 Chemical analysis

Trace metal concentrations throughout the grid were within the normal range for the north-east coast (Table 2). Metal determinations carried out on dredged material produced concentrations similar to those found in the sediments in the survey area. Analysis of tailings revealed higher concentrations of nickel and cadmium, which were possibly a result of contamination by oil used during the flotation process (see Table 1).

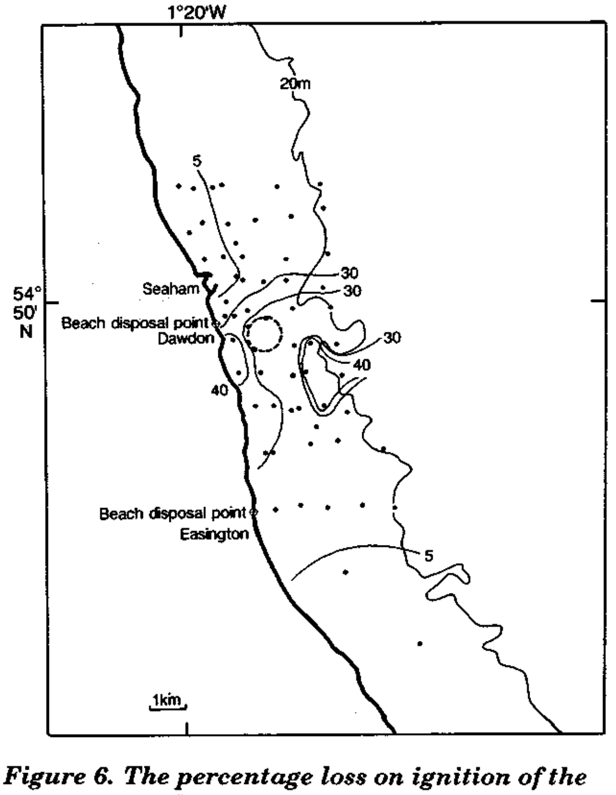

Figure 6. The percentage loss on ignition of the sand fraction in 1989

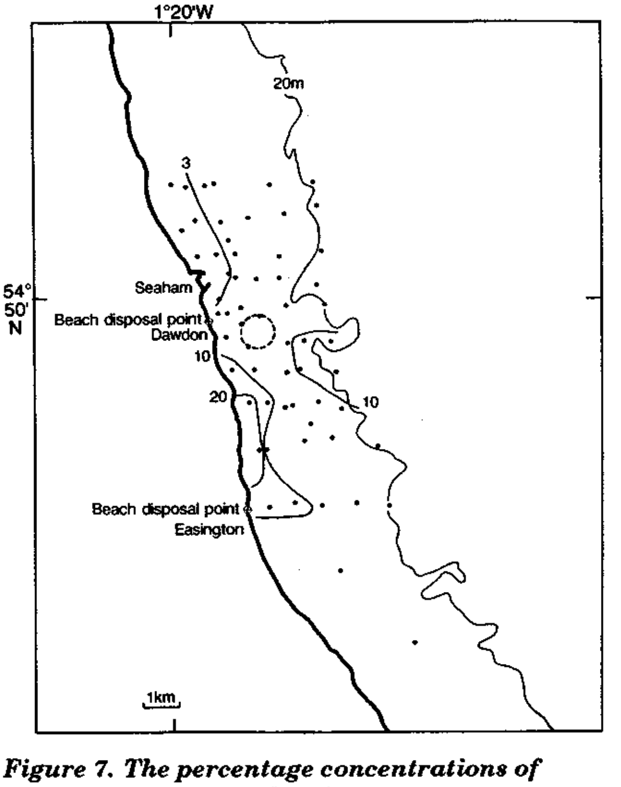

Figure 7. The percentage concentrations of organic carbon in 1989

Table 2. Concentration of metals in whole sediments (mg kg⁻¹). Values below the limit of detection for cadmium (0.2 mg kg⁻¹) are indicated by the less than symbol (<)

Station number	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	<	17	19	0.06	9	37	80
2	0.24	28	23	0.08	16	49	88
3	<	35	32	0.13	21	47	93
4	<	45	39	0.17	28	68	100
5	<	17	6	0.04	7	51	67
6	0.43	26	17	0.09	13	55	83
7	0.36	35	23	0.18	17	64	93
8	0.47	42	33	0.18	24	60	88
9	0.37	30	28	0.15	24	37	74
10	0.31	21	17	0.10	13	43	77
11	0.25	21	16	0.08	12	42	81
12	0.38	21	16	0.06	11	38	88
13	0.35	27	17	0.12	13	44	86
14	0.33	15	11	0.05	8	55	66
15	0.21	17	12	0.06	9	26	68
16	0.20	13	8	0.03	7	40	45
17	<	18	12	0.05	9	59	67
18	0.25	10	6	0.03	6	36	47
19	0.54	14	19	0.07	15	49	96
21	<	53	51	0.30	36	92	110
22	<	46	42	0.20	31	57	93
23	<	26	18	0.10	16	53	72
24	<	33	28	0.19	20	60	80
25	0.29	17	15	0.08	11	40	56
26	0.22	42	34	0.09	30	30	69
27	<	19	11	0.04	11	39	65
28	0.30	12	7	0.04	5	46	67
29	0.20	21	18	0.08	13	42	77
30	0.23	40	36	0.15	26	58	91
31	<	45	47	0.23	34	71	91
32	<	26	38	0.12	29	48	76
33	<	29	42	0.10	35	39	64
35	<	27	18	0.10	16	53	67
36	0.20	28	30	0.18	25	51	79
37	<	37	32	0.20	31	68	94
38	<	40	39	0.24	31	72	93
39	<	42	39	0.20	34	64	80
40	<	26	13	0.06	15	39	68
41	0.27	21	28	0.11	18	42	94
42	<	31	46	0.11	35	46	62
43	<	19	57	0.15	28	36	50
44	<	23	41	0.21	29	41	76
45	<	37	33	0.12	26	55	84
46	<	40	41	0.12	33	66	83
47	0.36	23	19	0.05	18	57	81
48	<	33	24	0.37	21	64	81
49	<	14	12	0.04	8	26	52
50	<	36	40	0.17	32	54	83
51	0.39	20	32	0.13	19	41	85
52	<	19	38	0.13	23	36	120
53	0.60	18	54	0.17	22	38	190
54	<	21	36	0.13	25	35	80
55	0.20	37	37	0.13	32	39	60
56	0.51	51	42	0.24	34	75	90
57	<	19	17	0.10	14	45	77
60	<	35	37	0.17	27	52	80
61	0.20	21	15	0.09	12	44	67
62	<	19	14	0.07	12	26	61
63	<	17	9	0.05	8	38	60

Fish and edible crabs, collected at Seaham in 1986, were analysed for total hydrocarbon content as an indicator of their contamination by flotation oil. Results indicate that there was no contamination of these organisms as a consequence of flotation oil associated with colliery tailings (R. Law pers. comm.; Table 3).

Table 3. Total hydrocarbon content (THC) (mg g^{-1} dry weight) of fish and shellfish collected off Seaham in 1986

Sample	THC
Whiting muscle	5.8
Whiting muscle	4.5
Flounder muscle	9.5
Flounder muscle	8.3
Crab claw	7.0
Crab hepatopancreas	44.0

3.4 Microscopic analysis

All of the samples were observed individually under a light microscope, in an attempt to identify a physical characteristic of one or more of the wastes that could be identified in the marine sediments. This would have allowed confirmation of the presence of that waste at a particular location, but the similarity of the colliery wastes and dredged material to natural sediments made such discrimination difficult. The presence of brick particles in the dredgings however acted as a marker for that waste. The fragments were found to be most common in the inshore half of the grid, with the exception of a coarse patch of ground between Seaham and the dredged material disposal site (Figure 8) where they were absent. Higher numbers of brick fragments were also found in an offshore area, indicating some offshore transport.

3.5 Sediment transport

Observation of the sea bed (e.g. ripple marks; see Figure 2(a)) indicated that the survey area is an active sediment transport environment.

3.6 Core samples

The core sample collected south of Seaham (station 59; see Figure 1) was composed of mud and sand laminae, with mud being dominant at the top of the core and sand dominant towards the bottom (Figure 9). Brick and coal particles were common in the sand layers.

The core collected north of Seaham (station 58; see Figure 1) was quite different. The entire length of the core was composed of sand with no evidence of any mud laminae. Brick particles were rare and the coal content was much lower than that found in the core collected south of Seaham.

3.7. Particle size analysis

Full particle size analysis was carried out on all of the samples taken in connection with this survey (Figures 10-11). Analysis of particle size data indicated a diversity of sediment types over the survey area. Stations possessing a fluid mud-type sediment were readily identified due to their high fines content.

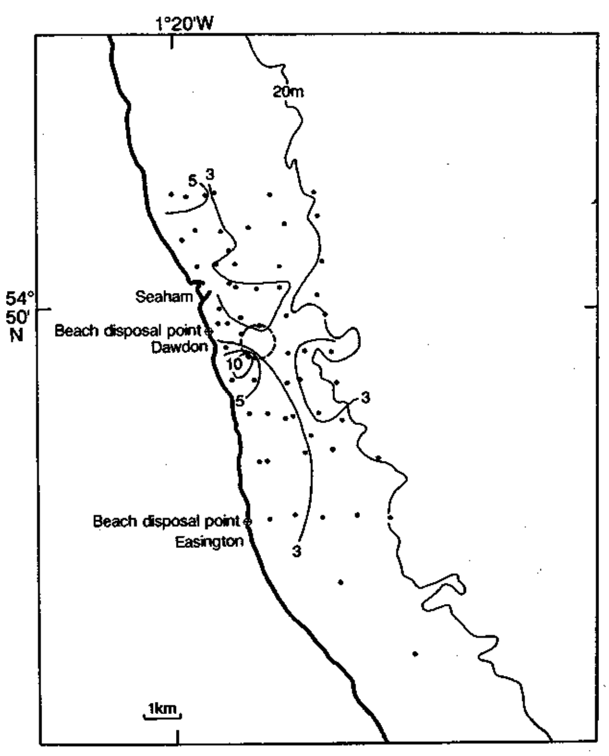

Figure 8. The distribution of brick fragments in 1989

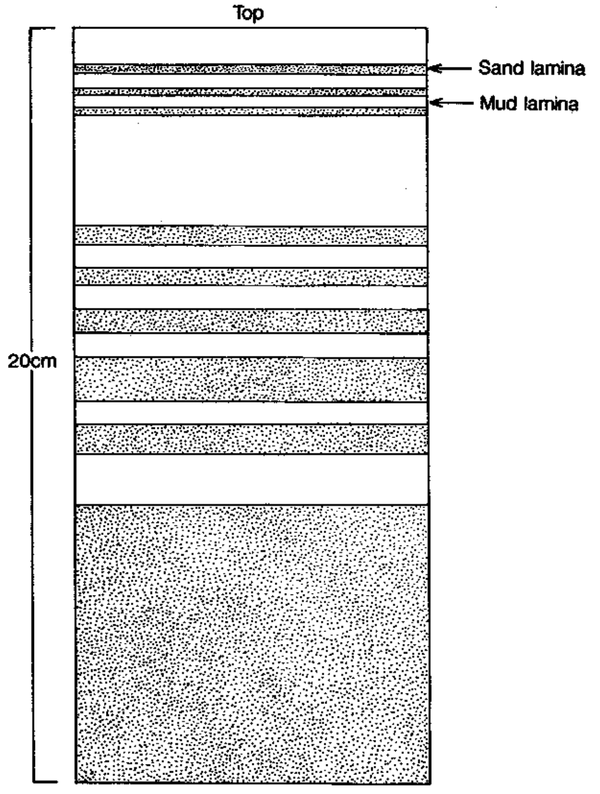

Figure 9. Diagramatic description of a core sample taken at station 59 in 1989

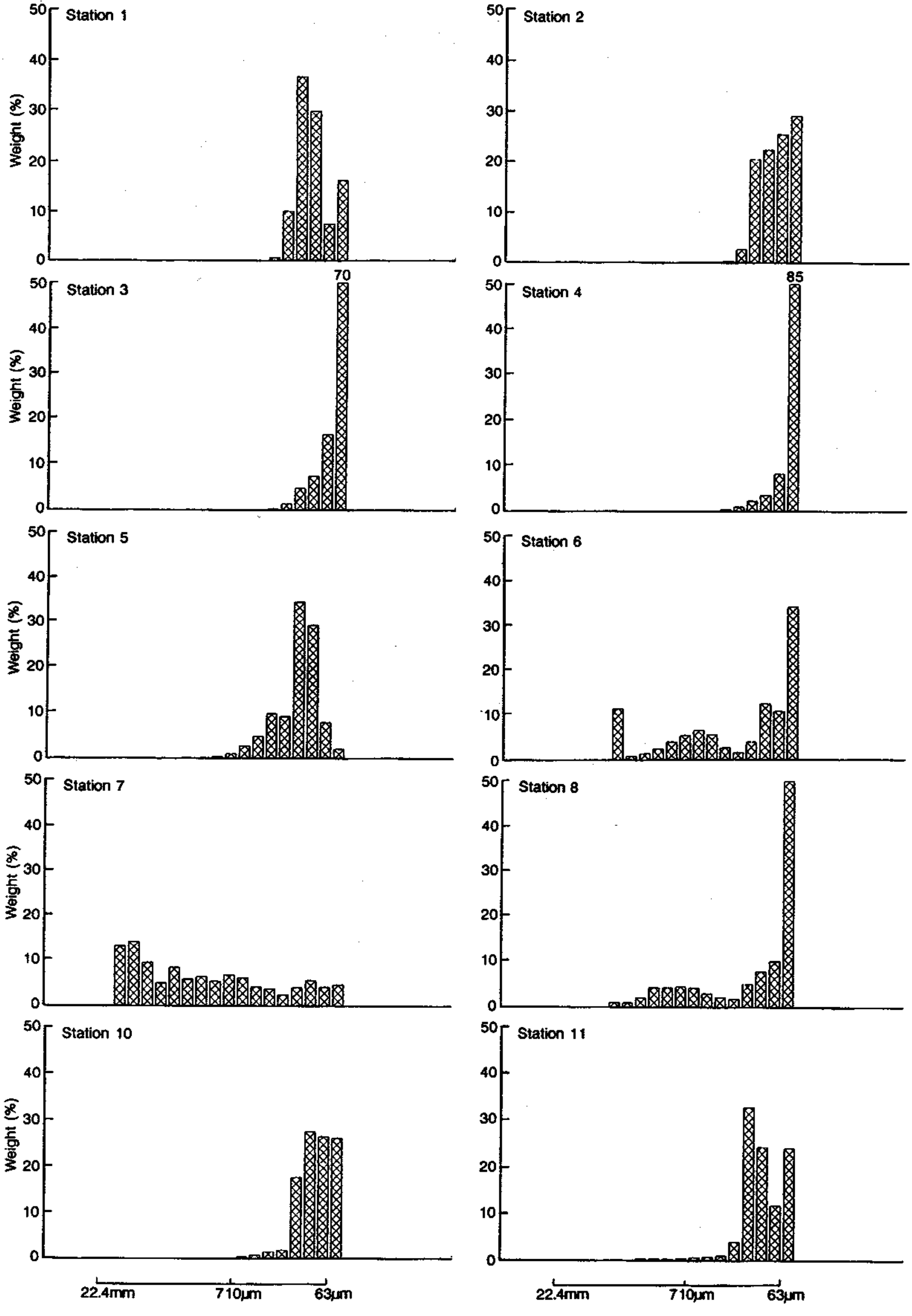

Figure 10. Particle size distribution at stations 1-11in 1989
Note: If the sediment weight in a single size class exceeds 50% the actual figure is noted at the top of the column

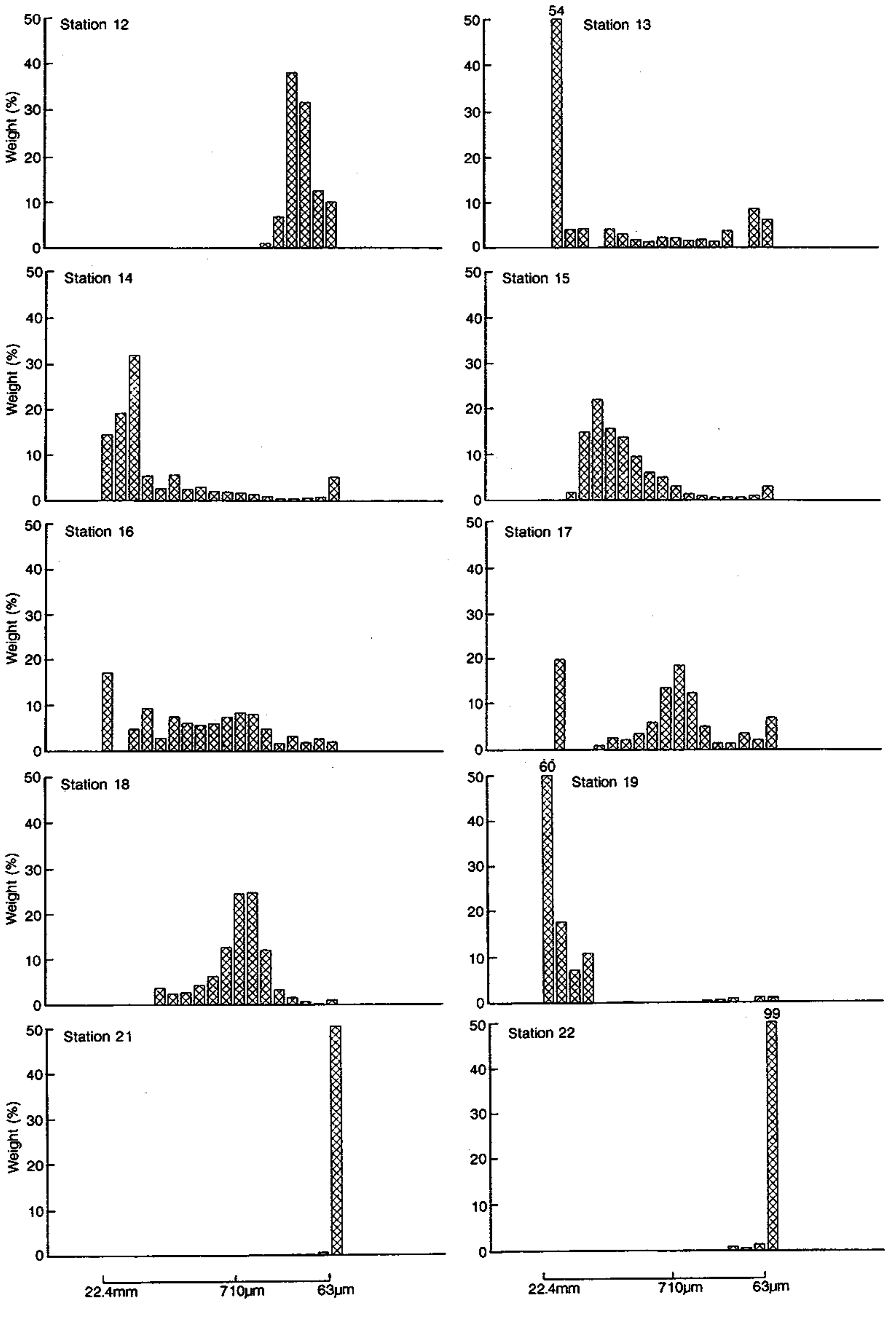

Figure 10 (Continued). Particle size distribution at stations 12-22 in 1989

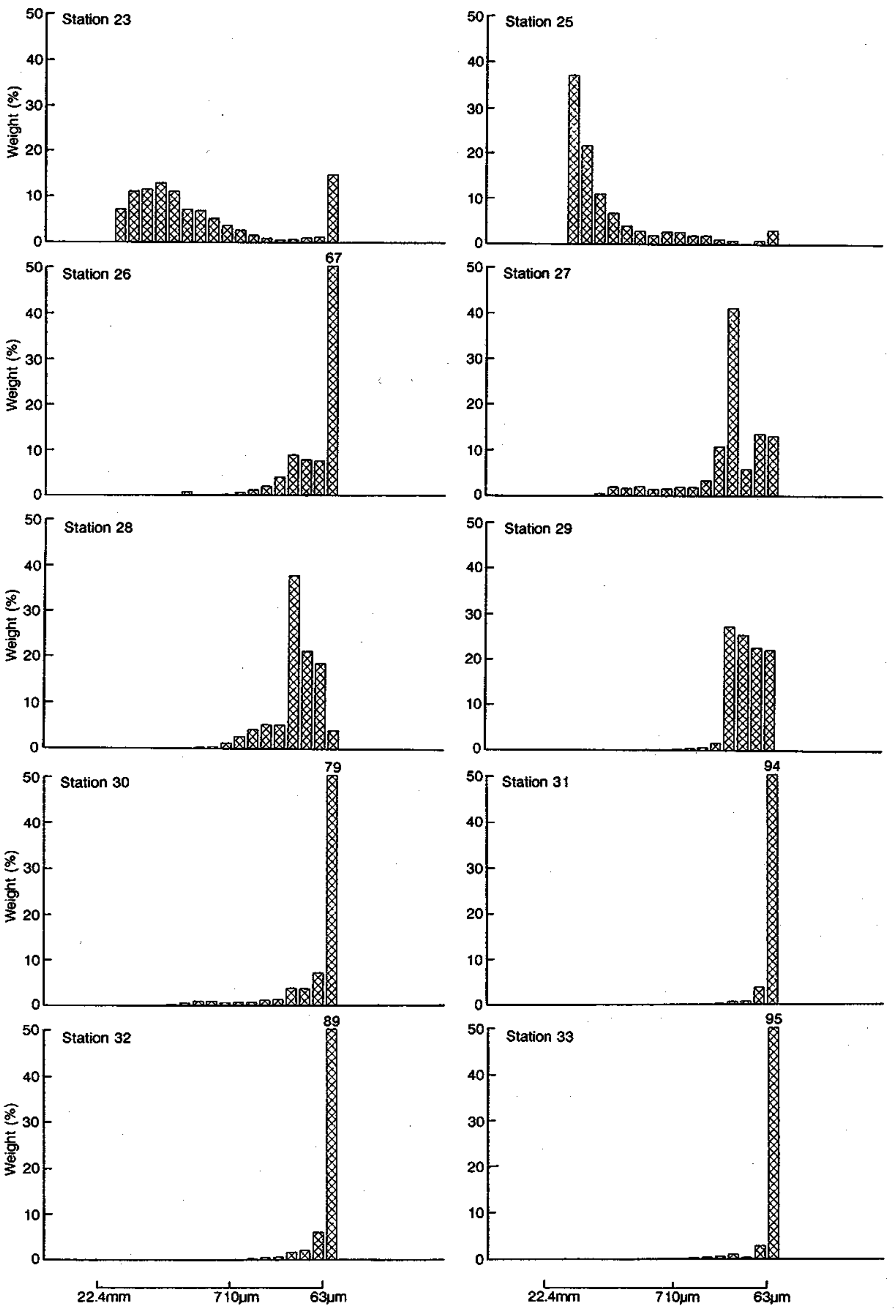

Figure 10 (Continued). Particle size distribution at stations 23-33 in 1989

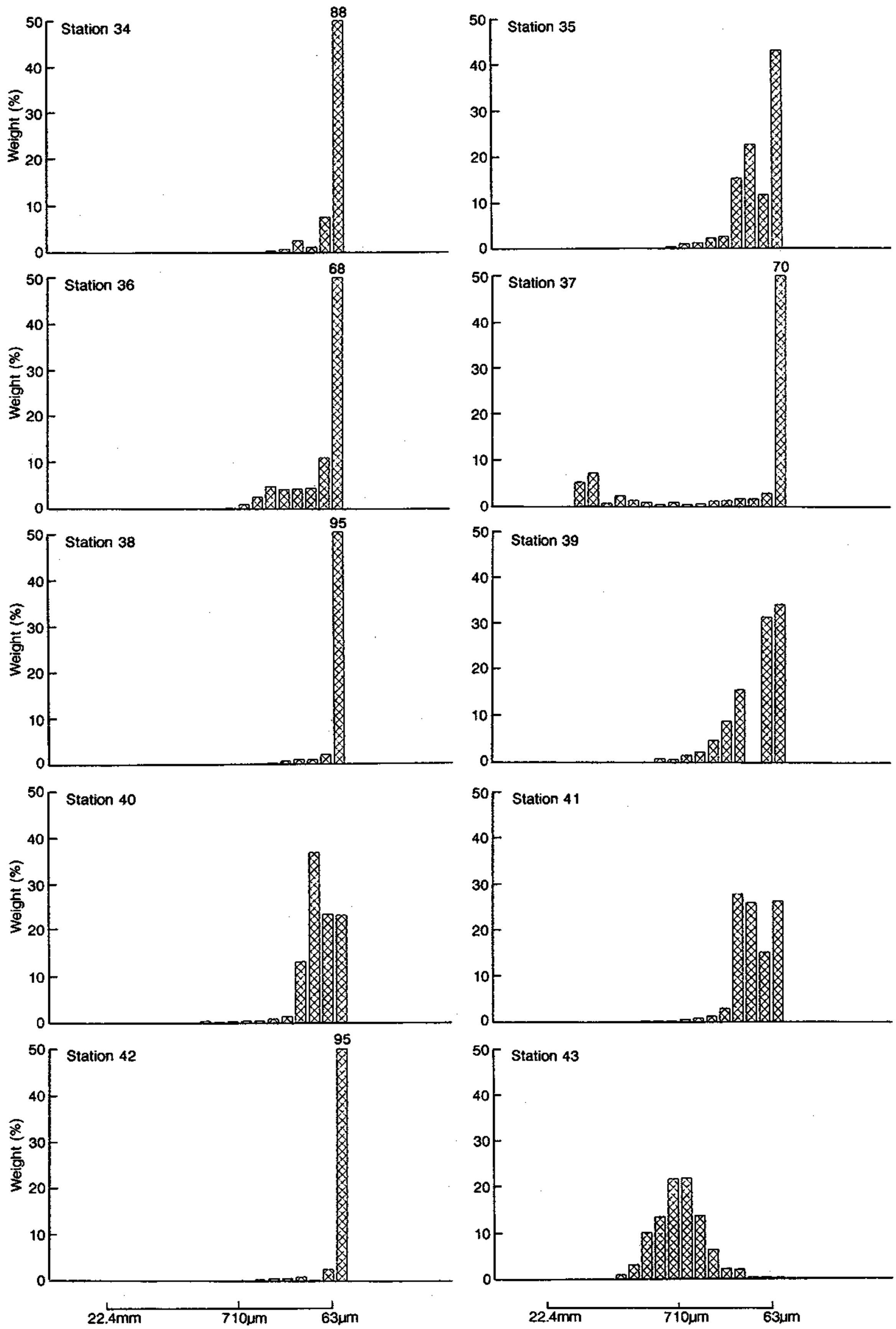

Figure 10 (Continued). Particle size distribution at stations 34-43 in 1989

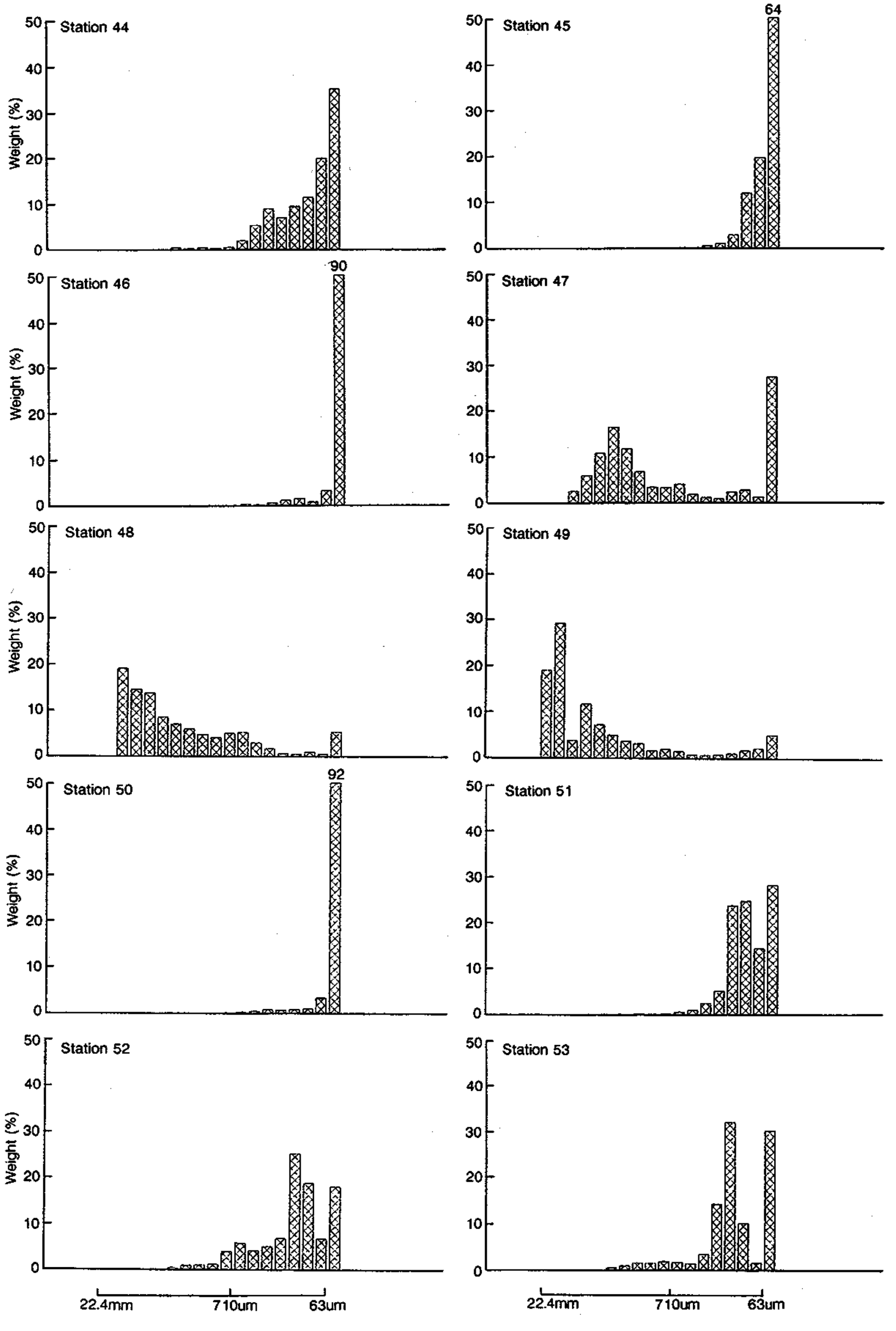

Figure 10 (Continued). Particle size distribution at stations 44-53 in 1989

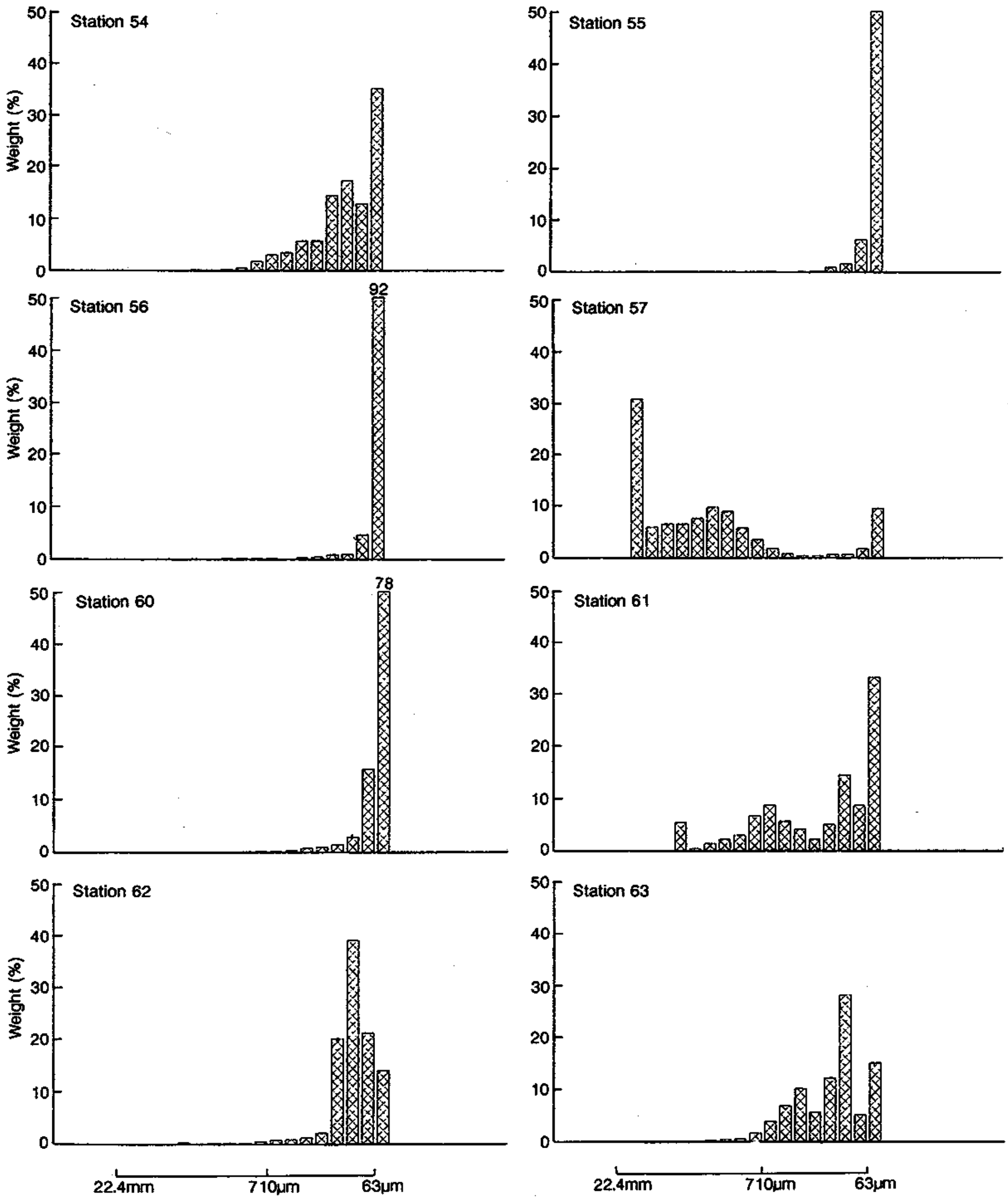

Figure 10 (Continued). Particle size distribution at stations 54-63 in 1989

4. DISCUSSION

Each year, about 2.2 x 10^6 tonnes of colliery waste are deposited on the beach at Dawdon. Most of this material is transported by wave action, particularly during storms, into the nearby areas of the sea. Despite this input, divers found no visual evidence of any significant accumulation of waste on the nearshore sea bed, nor any evidence of smothering of the local rocky areas which are of particular concern due to their potential as crab and lobster habitat.

Rowlatt *et al.* (1990) showed that minestone deposited from ships, in water of 20 m depth off Wearmouth, is dispersed after breakdown into smaller particles. The degradation process is likely to be faster in beach and shallow water areas such as Dawdon, where minestone deposits are exposed to higher energy wave activity than in deep water and may also be subject to wetting/drying cycles. The degradation products of minestone are predominantly sand, sandstone and shale particles with some coal. This is similar in constitution to tailings, which are in essence the fine fraction of mine waste. As many strata exposed along the north-east coast are similar to those from which the minestone and tailings are derived, it is not surprising that the mine wastes bear a marked similarity to the natural sediments in the area. The main distinguishing feature

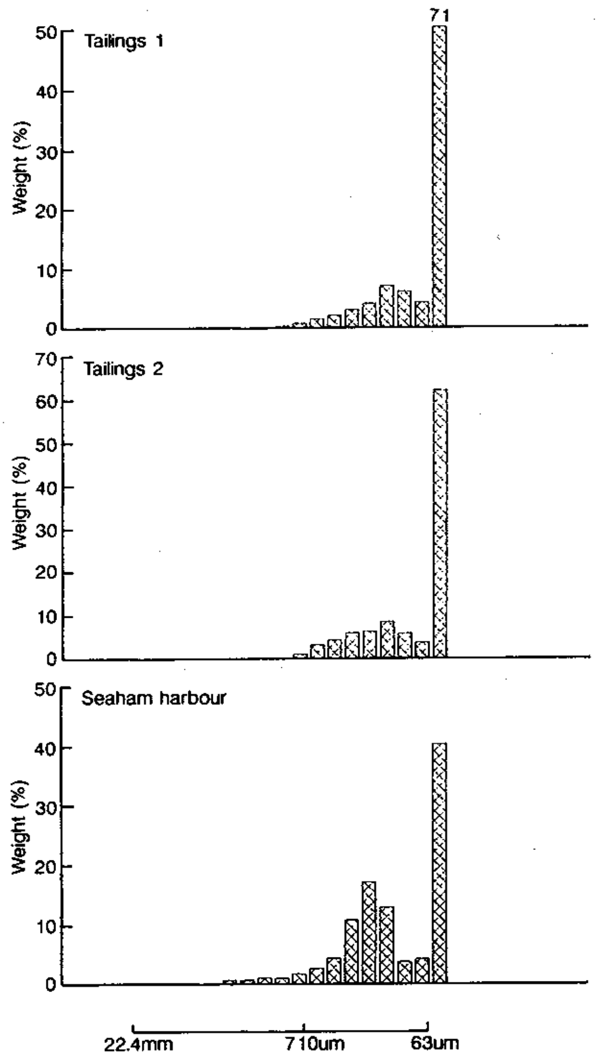

Figure 11. Particle size distribution for waste material on the beaches and at Seaham harbour in 1989

of the wastes is the presence of residual coal, which is not extracted during the washing procedures. The distribution of coal in the nearshore sediments therefore may be used as a marker for the distribution of minestone, although it must be borne in mind that the coal is less dense than the rock particles and may, after some attrition and transportation, become separated from the rest of the mine waste.

Chemical analysis of the sediments, which is a more sensitive technique than visual observation, shows that those stations near the beach disposal site contain a higher concentration of coal (as determined by LOI) in the sand fraction than sediments in the north and south of the survey area. This observation broadly confirms those made by Eagle *et al.* (1979), although the present survey also indicates an area 4 km offshore from Dawdon where high values of LOI in the sand fraction were observed. It must be borne in mind that the LOI values only relate to the sand fraction and therefore cannot be viewed as an indicator of whole sediment-coal content which is shown by the distribution of whole sediment- carbon concentrations (see Figure 7). The highest concentrations occur about 2 km to the south of the beach disposal site with slightly elevated values offshore from Dawdon where the highest LOI in sand values occur. Few of the other chemical data show distributions which are helpful in understanding the distribution of coal waste. Taking the visual observations and organic carbon data together, it can be deduced that the mine wastes are transported away from the nearshore zone, probably after breakdown into smaller particles, and then incorporated into the general transport regime in that part of the North Sea. There is some evidence of coal close to the tipping site, but on the evidence provided by this survey it is not significant and does not compromise the crab and lobster habitat. Of course, it is possible that there is an occasional build-up of waste at the sea bed which is then removed during storms. However, the present diving survey took place at the end of the summer after a relatively quiescent period when it might be expected that any tendency for waste accumulation would be most apparent. It can therefore be deduced that even under relatively calm conditions the mine waste is dispersed from the nearshore zone.

Further offshore, in deeper water, quiescent conditions might have led to the accumulation of the observed mud. The fluid nature of the muddy sediment makes it highly pone to resuspension (e.g. during storm events or spring tides). This could be followed by deposition over any part of the survey area, including the rocky ground. A visual description of the core sample taken at station 59, south of Seaham, confirms that periods of mud deposition have occurred from time to time as alternating laminae of mud and sand of varying thicknesses are apparent down the core.

It seems that, on some occasions, the sandy sediment is deposited over the muddy substrate, stabilising it and creating mud laminae. On other occasions, the mud may be resuspended and transported elsewhere before a stabilising sand layer can form. The core sample collected north of Seaham does not have mud laminae. This would suggest either that mud is never deposited here or, if it is, that it does not remain *in situ* for long enough for it to be buried by sand. Markers which might identify the presence of colliery waste and dredged material are not present in the mud to any great extent. This suggests that disposal operations are not chiefly responsible for the accumulation of fine material offshore. However, as dredged material disposal is carried out over the muddy area, and colliery waste disposal occurs adjacent to the fines deposits, it is likely that both operations make at least a limited contribution towards the presence of fine material over the area covered by the survey.

Coal concentrations are lower in the northern part of the grid than they are at most stations to the south.

This suggests that the transport of colliery waste derived material is in a southerly direction, which is in agreement with the general southward current observed by Eagle *et al.* (1979). Samples collected in the extreme south of the survey area show low levels of coal, which suggests that the effects of disposal operations are diluted quickly by natural sediments.

5. CONCLUSIONS

Observations made during the survey and analyses carried out subsequently are consistent with the general pattern of sediment movement reported by Eagle *et al.* (1979). They also indicate that at the time of the survey there was no significant accumulation of colliery waste in the nearshore zone and no evidence of any smothering of areas which provide habitat for crabs and lobsters.

Acknowledgement

The authors would like to thank the MAFF diving team for carrying out a thorough and successful survey.

The reference to proprietary products in this report should not be construed as an official endorsement of these products, nor is any criticism implied of similar products which have not been mentioned.

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