Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

CEH Dorset

Winfrith Technology Centre
Winfrith Newburgh
Dorchester
Dorset DT2 8ZD

Telephone (01305) 213500
Main Fax (01305) 213600
www.ceh.ac.uk

Monitoring Poole Harbour Bird Invertebrate Prey Availability: Sediment Sample Collection

R W G Caldow, S McGrorty
S E A le V dit Durell, A D West and R A Stillman

Project Leader: Dr Richard W G Caldow
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1. OVERVIEW

This report describes a sediment-sampling programme conducted by the Centre for Ecology and Hydrology (CEH) for the Environment Agency as part of a larger project for English Nature entitled 'Monitoring Poole Harbour Bird Invertebrate Prey Availability'. The report details the background to the sediment-sampling study, its objectives, the methodology employed in collecting and processing the samples, and a brief summary of the results. The full dataset is presented in tabular format and several maps summarising the data are also presented.

2. BACKGROUND

Poole Harbour is one of the most important estuaries in Britain for birds, with over 28,000 waders and wildfowl feeding on the mudflats during the winter months. In recognition of its importance the Harbour was recently designated as an internationally important Special Protection Area. One of the requirements of this designation is to ensure that the habitats used by these birds are kept in good condition. Accordingly, English Nature commissioned the Centre for Ecology and Hydrology (CEH) to undertake a harbour-wide survey of the intertidal mud and sand-flats to quantify the numerical and biomass densities of the invertebrates that constitute the birds' food resources. The Environment Agency, which was involved in the planning of this project, required that sediment samples be collected from across the harbour for a variety of analytical purposes. This report deals solely with the collection and processing of these sediment samples. The results of the invertebrate survey will be presented in a contract report to English Nature to be completed in the second half of 2003.

3. OBJECTIVES

The objectives of the sediment-sampling programme were as follows.

1. To collect samples of surface sediment for the purpose of analysis for their metal content.

2. To collect samples of surface sediment for the purpose of analysis of their Total Organic Carbon (TOC) content.

3. To collect samples of surface sediment for the purpose of Particle Size Analysis (PSA).

4. METHODOLOGY

4.1 Survey Plan

At the outset of the larger project to survey the invertebrate food resources of Poole Harbour's bird populations (to which this sediment sampling project was supplementary) there was no definitive plan as to the distribution of the sampling effort across the harbour. Following discussions between CEH, English Nature and the Environment Agency, it was decided that 80 sampling stations should be surveyed and that these should be spread evenly throughout the entire intertidal areas of Poole Harbour rather than being concentrated solely in those 'more important' parts of the harbour known to be favoured bird-feeding areas. This was deemed to be the most appropriate way in which to gather information on the *potential* food resources available throughout the harbour, irrespective of whether they are currently exploited by the existing populations of birds. It was also agreed that the best protocol (and one that could be applied easily to other locations) for establishing a standard set of baseline sampling stations, which could be revisited in future monitoring exercises, was to utilise the intersections of the Ordnance Survey grid to define the locations of the sampling stations. A grid of 500 m by 500 m resulted in 80 intersections falling between Mean High Water and Mean Low Water as marked on the Ordnance Survey Explorer OL15 map. It was decided that restricting the sampling locations to lie within these tidal bounds was a more appropriate way in which to sample sites to which birds gain access on a regular basis, rather than extending the lower sampling limit to all areas above Lowest Astronomical Tide (as marked on the IMRAY Yachting Chart Y23). The precise location of each sampling station was determined to the nearest meter from the OS grid coordinates. Further discussions between CEH and the Environment Agency resulted in a decision to collect sediment samples from all sampling stations within Lytchett Bay (n=4), Holes Bay (n=9) and at alternate stations throughout the rest of the harbour (n=33) giving a total of 46 sediment sampling stations.

Further discussions between CEH and Environment Agency resulted in a sampling protocol for each sediment sampling station. The methodology associated with each component of the survey is detailed in the following sections.

4.2 Locating the Sampling Stations

The survey was conducted over September and October 2002. Sampling stations were visited either on foot or with the aid of the Royal National Lifeboat Institution (RNLI) hovercraft at low water on spring tides, or by boat over high water on neap tides. Samples were collected from as close as practically possible to the pre-determined locations of the sampling stations. A hand-held GPS was used to record the precise coordinates at which each sample was actually taken. Records were made at each sampling station of any noteworthy features e.g. presence of vegetation, shell beds, sediment characteristics etc.

4.3 Sediment Sampling

4.3.1 Metals

At each of the 46 sampling stations a number of scrapes of the surface sediment (top 1 cm, and avoiding black anoxic material if possible) were taken using a stainless steel scoop provided by the EA until a 500 ml plastic pot labelled with the sampling station number had

been filled with sediment. At those sampling stations at which the sediment was entirely anoxic a surface sample of sediment was, nonetheless, taken. These sediment samples were frozen on return to the laboratory at CEH and passed to the Environment Agency at Blandford at a later date for subsequent chemical analyses.

4.3.2 Total Organic Carbon (TOC)

At each of the 46 sampling stations a number of scrapes of the surface sediment (top 1 cm, and avoiding black anoxic material if possible) were taken using a stainless steel scoop provided by the EA until a 250 ml plastic pot labelled with the sampling station number had been ¾ filled with sediment. At those sampling stations at which the sediment was entirely anoxic a surface sample of sediment was, nonetheless, taken. These sediment samples were frozen on return to the laboratory at CEH and passed to the Environment Agency at Blandford at a later date for subsequent chemical analyses.

4.3.3 Particle Size Analysis (PSA)

At each of the 46 sampling stations a stainless steel scoop provided by the EA was used to take a sample of the surface sediment to a depth of 5 cm (regardless of the presence/absence of black anoxic material). This was placed in a 120 ml plastic pot labelled with the sampling station number. These sediment samples were frozen on return to the laboratory at CEH and processed as outlined below.

The amount of liquid in all containers was minimised as far as was practically possible, given that many sediment samples had to be taken through the water column at sampling stations that were visited by boat over high water on neap tides. The stainless steel scoop was washed in seawater between each sampling station.

4.4 Particle Size Analysis

The 46 sediment samples were stored frozen. Before analysis, thawed samples were thoroughly mixed and a sub-sample of c30-50 ml passed through a 1 mm sieve to remove any invertebrates, algae, other detritus (e.g. shell fragments) and any sediment particles >1 mm in diameter. Particle size distribution between 0.1 and 1000 μm was determined from the sieved sub-sample using a Coulter LS130 laser diffraction analyser. This machine automatically recalibrates various functions between samples and is serviced annually and tested against a series of industrial standards. In the case of samples in which there were inorganic mineral sediment particles > 1 mm in diameter (n=11), a note has been made in the data set of the nature of these particles (see Table 2), but the contribution of these coarse particles to the overall sediment sample composition has not been analysed volumetrically.

5. RESULTS

5.1 Location of Sampling Stations

The pre-determined location of each sampling station, the actual location at which the samples were taken and the details of each sampling station are presented in Table 1.

Stations visited on foot were generally sampled very close to the OS grid intersections, except where the weather conditions (wind, rain and atmospheric pressure) meant that the tide had not exposed the location as expected, or where upshore sampling stations assumed, from the OS map, to be on intertidal flats turned out in the field to fall just within beds of *Spartina* or to be just above the high water mark. In all these cases, samples were taken from intertidal locations as close as possible to the OS grid intersection. The same constraints on reaching precise OS grid intersections also applied to locating the sampling stations visited by hovercraft. In addition, however, in order to avoid excessive disturbance to the sediment in the vicinity of sampling stations, in the course of fine manoeuvring of the hovercraft to the precise location, samples were often taken where the hovercraft came to rest provided that was within what was considered to be an acceptable distance of the desired location. In the case of stations visited by boat over high water, there were always errors in locating OS grid intersections precisely due to the drifting effects of wind and tide on the boat once anchored. In spite of these practical difficulties, the average deviance along the east-west and north-south axes between the true OS grid intersections at which the samples were to be taken and the actual location at which the samples were taken was 36 m. Over half of the deviance measures were less than 20 m. Given the minimum distance of 500 m between neighbouring sampling stations we consider these deviances to be unimportant. The actual location of each of the 46 sampling stations at which sediments were collected for the Environment Agency is shown in Figure 1.

5.2 Characteristics of Sampling Stations

Sixteen of the 36 sampling stations at which the extent of algal cover was scored quantitatively had none present, 3 had up to 10% cover, a further 4 had between 10 and 50% cover, 3 had between 50 and 90% cover and 10 had 90% or more green algal cover.

Thirty six sampling stations were visually classed as consisting of ‘mud’ at the surface, one was assessed as being ‘muddy-sand’, four as being ‘sandy’ (medium-coarse), two as being ‘sandy’ (gravel), one as consisting of ‘shells’ and one as being ‘jelly-like’.

Of the 41 sampling stations at which the colour of the surface sediment was scored, it was assessed as being aerobic and ‘grey’ at one, and aerobic and brown at 35. The average thickness of this aerobic layer at these 36 sites was, however, only 5.5 mm. The surface sediment was assessed as being black at 5 stations (33, 45, 48, 51 and 66). At these 5 stations the sediment was anoxic to a depth of at least 30 cm (as determined from the invertebrate cores taken for English Nature).

The sub-surface sediment at 38 sampling stations was visually classed as consisting of ‘mud’. The sub-surface sediment was assessed as being ‘muddy-sand’ at one station, as ‘sandy’ (medium-coarse) at four, and as ‘sandy’ (gravel) at two.

Of the 38 sampling stations at which the colour of the sub-surface sediment was scored, it was assessed as being 'brown' at one, 'grey' at five, 'grey/black' at one, 'black/grey' at two and completely 'black' at 29.

5.3 Particle Size Analysis (PSA)

The results of the Particle Size Analyses are presented in Table 2. Figures 2-11 depict the sediment characteristics (mean, median and modal particle sizes and the % particles <20 μm, 20-63 μm, 63-125 μm and >125 μm) at each sampling station around the harbour.

At 22 out of 46 stations, more than 50% of the particles were smaller than 20 microns (i.e. fine silt and clay) and at 23 stations more than 80% of the particles were less than 63 microns (i.e. "fines" = fine and coarse silt and clay). At 23 stations more than 20% of the particles were larger than 63 microns (i.e. sand) and at eight stations, more than 50% of the particles were sand. At 24 stations more than 10% of the particles were larger than 125 microns (i.e. medium-coarse sand) and at 7 stations (33, 65, 71, 75, 76, 79 and 80) more than 50% of the particles were of this size.

Across the harbour as a whole, the finest surface sediments in terms of mean, median and modal particle sizes (Figures 2-4) occurred towards its western end near the mouths of the Rivers Frome and Piddle, in the two large embayments on its northern shore i.e. Lytchett Bay and Holes Bay, and the upper reaches of some of the creeks on its southern shore i.e. Middlebere Lake and Wytch Lake. The coarsest surface sediments in terms of the mean, median and modal particle sizes (Figures 2-4) occurred on the heavily built-up shores along the northern and particularly eastern parts of the harbour i.e. near Rockley Sands, the Baiter, Parkstone Bay and Whitley Lake and on the 'southern' side of the harbour along the shores of Stone Island Lake and White Ground Lake.

In terms of the proportionate make-up of the sediment, the sampling stations with the highest percentage of fine silt and clay (<20 microns) were in the Wareham Channel, Lytchett Bay, Holes Bay and Middlebere and Wytch Lakes (Figure 5). The other bays along the southern shore of the harbour (Newton Bay and Brands Bay) had a somewhat lower, but still appreciable, percentage of particles <20 microns (Figure 5). Variation between sites in the percentage of coarse silt (20-63 microns) (Figure 6) showed the same distribution around the harbour as that for fine silt and clay. However, one interesting feature here is the difference between the two lines of sampling stations running up the two channels in Holes Bay. The stations on Upton Lake have a noticeably higher percentage of coarse silt than the stations on the Creekmoor Lake (Figure 6), which are more 'sandy' (Figure 7). Virtually all of the sampling stations in the Wareham Channel, Lytchett Bay, Holes Bay and along the eastern end of the southern shore of the harbour contained a fraction of particles >63 microns i.e. sand (Figure 7). The most uniformly silty sediments, virtually completely lacking in a sandy component, were in Middlebere and Wytch Lakes (Figures 7, 10).

The sampling stations with the highest percentage of fine sand (63-125 microns) were along the Wareham Channel, and in the southern half of Holes Bay and, to a lesser extent, those around the South Deep (Figure 7). Coarse sand (i.e. particles >125 microns) was absent from Middlebere and Wytch Lakes and virtually absent from the whole of the Wareham Channel, Lytchett Bay and the northern half of Holes Bay (Figure 8). A low percentage of coarse sand was present at the stations in the southern half of Holes Bay and around South Deep and on

the Studland shore of Brands Bay (Figure 8). Sampling stations with a high percentage of coarse sand were restricted to the heavily built-up shores on the northern and eastern parts of the harbour i.e. near Rockley Sands, the Baiter, Parkstone Bay and Whitley Lake (Figure 8). There was also a lot of coarse sand at sampling stations at Gravel point and on the southern shore of Brownsea Island (Figure 8). Coarse sand was very much restricted to the eastern end of the harbour near the harbour entrance (Figure 8).

There were 11 sampling stations at which the surface sediment samples contained particles greater than 1mm in diameter. All of these were in the eastern half of the harbour. In four cases these particles comprised shell fragments (stations 56, 57, 62 and 64). At a further four stations these particles were quartz grit (stations 37, 60, 76 and 80) and at three stations there was a fraction of gravel or small stones (stations 65, 71 and 80). In the case of the samples that contained quartz grit, this was a very minor component of the sediment, literally a few grains per sample. Only in the case of stations 65, 71 and 80 where the coarse particles comprised gravel and small stones did these coarse particles constitute a significant proportion of sediment volume.

6. DISCUSSION

The surface sediment of the majority of the intertidal areas between Mean High Water and Mean Low Water in Poole Harbour is dominated by fine silt and clay (<20 microns). The majority of sampling stations consisted of between one third and two thirds fine silt and clay and up to one-third coarse silt (20-63 microns). Thus, 38 out of 46 sampling stations had surface sediment that consisted of in excess of 50% silt and clay particles (Figures 9 and 11). In fact, there was very little true clay (<=2 microns) in any of these samples, the percentage of particles with a diameter of 2 or less microns being in the range of 3-10% at all 46 stations. Only 8 sampling stations had surface sediment that consisted of in excess of 50% sand particles (Figures 10 and 11). Silty surface sediments probably account for more than 83% (i.e. 38/46) of the intertidal surface area of Poole Harbour because the 8 predominantly 'sandy' stations were restricted to very narrow shores. This pattern fits broadly with the expectation that finer sediments accumulate in more sheltered areas and where tidal currents/flow is low.

The majority of sampling stations had a very thin aerobic surface layer over a grey/black anoxic sub-surface. In some areas, the sediment was completely anoxic. In addition, approximately one third of the sampling stations had a noticeable surface film of brown diatoms. These observations, in combination with the domination of the silt fractions of the sediment over much of the harbour suggest a low-energy system in which the surface sediment is subject to very little disturbance over long periods of time. This will clearly have implications for the susceptibility of the harbour sediments to pollutants such as heavy metals and organic compounds.

7. ACKNOWLEDGMENTS

We are grateful to the Royal National Lifeboat Institution for allowing CEH to make use of their hovercraft during the course of this survey. We are particularly thankful to Mr Tony Stankuss of the RNLI for his time, patience and skill in piloting us around the sampling stations in the hovercraft.

Table 1 The mapped location (OS grid intersection), actual sampling location, date and time of sampling, and characteristics of the 46 sediment-sampling stations

Station	Map Location	Actual OS Sheet	Actual Eastings	Actual Northings	Date	Time
2	SY9450088000	SY	94550	88048	17/09/2002	13:15
3	SY9450088500	SY	94435	88459	17/09/2002	13:30
4	SY9500087500	SY	94932	87593	17/09/2002	12:10
8	SY9500089500	SY	95006	89481	17/09/2002	16:10
10	SY9550088000	SY	95502	87983	16/09/2002	
11	SY9550088500	SY	95492	88515	17/09/2002	14:20
12	SY9550089000	SY	95510	89059	17/09/2002	14:45
15	SY9550090500	SY	95494	90494	21/09/2002	14:43
17	SY9600089500	SY	95991	89570	21/09/2002	15:10
18	SY9600090000	SY	95978	90016	21/09/2002	17:30
22	SY9650090500	SY	96495	90462	21/09/2002	16:40
27	SY9700092000	SY	97000	92014	30/09/2002	12:25
28	SY9750091500	SY	97502	91500	30/09/2002	11:45
29	SY9750092000	SY	97487	92026	30/09/2002	13:45
30	SY9800086000	SY	98036	86089	18/09/2002	11:40
31	SY9800087000	SY	97880	86957	18/09/2002	11:10
32	SY9800089000	SY	98047	89032	18/09/2002	13:40
33	SY9800090500	SY	98000	90500	11/09/2002	
34	SY9800092000	SY	97988	92033	30/09/2002	13:20
35	SY9850086500	SY	98500	86489	18/09/2002	15:30
37	SY9850087500	SY	98610	87514	18/09/2002	14:30
40	SY9900087000	SY	99012	86995	01/10/2002	13:35
41	SY9900088000	SY	99001	87985	01/10/2002	13:15
45	SY9950092000	SY	99485	91987	05/09/2002	13:55
46	SY9950092500	SY	99602	92425	01/10/2002	10:55
48	SZ0000087000	SY	99982	87077	20/09/2002	17:05
49	SZ0000091000	SZ	186	90994	05/09/2002	17:00
50	SZ0000091500	SZ	3	91537	05/09/2002	15:35
51	SZ0000092000	SZ	99891	92010	05/09/2002	14:30
53	SZ0050086000	SZ	456	85992	20/09/2002	16:20
55	SZ0050091000	SZ	507	91042	05/09/2002	16:40
56	SZ0050091500	SZ	500	91446	05/09/2002	16:25
57	SZ0050092000	SZ	533	92057	05/09/2002	16:00
58	SZ0050092500	SZ	500	92500	01/10/2002	11:30
60	SZ0100086500	SZ	956	86545	20/09/2002	15:57
62	SZ0150085500	SZ	1490	85553	19/09/2002	14:55
63	SZ0150086000	SZ	1500	86076	19/09/2002	15:15
64	SZ0150087000	SZ	1486	87000	19/09/2002	16:30
65	SZ0150087500	SZ	1511	87479	19/09/2002	16:50
66	SZ0200085000	SZ	2027	84950	19/09/2002	13:55
71	SZ0200090000	SZ	2007	90026	11/09/2002	
72	SZ0250086000	SZ	2499	85901	19/09/2002	16:05
75	SZ0300090500	SZ	3008	90506	06/09/2002	
76	SZ0350086500	SZ	3370	86360	11/09/2002	
79	SZ0450088500	SZ	4650	88462	06/09/2002	17:20
80	SZ0450089000	SZ	4615	88966	06/09/2002	17:45

Table 1 continued

Station	Shore-Level	Water Depth (cm)	Distance From Saltmarsh (m)	% Cover Green Algae
2		24		0
3		21		0
4		42	15	0
8		1	2	50
10				10
11		24		0
12		47		
15	high	54	1	100
17		15	2	100
18		5		5
22	high	29		0
27		25		0
28		20		0
29		52		0
30		25	<5	0
31		40	2	thick coat
32		70	near	lots
33				scattered
34		16	<1	95
35		1	30	
37		50		0
40		33	10	100
41		42	2	30
45		17	<5	100
46		17		50
48	high	0	5	70
49	high	0	20	100
50	low			present
51			<5	100
53		0		80
55	low			0
56	low	1		0
57	low	0		70
58		24		0
60		9		thick
62		3		90
63		12	a few spartina islands	thin
64		26		50
65		0		patchy
66		40	10	100
71	low			
72		38		90
75	mid	0		0
76				0
79	high	1		2
80	high	5		0

Table 1 continued

Station	Surface Substrate	Surface Colour	Surface Depth (cm)	Surface Texture
2	mud	brown	0.3	
3	mud	brown	3	soft
4	mud	brown	0.5	
8	mud	brown	0.2	soft
10	mud	brown	0.5	hard
11	mud	brown	0.5	
12	mud	brown	0.4	
15	mud	brown	0.1	soft
17	mud	grey	0	
18	mud	brown	1	soft
22	shells			hard
27	mud	brown	0.3	soft
28	mud	brown	5	soft
29	mud	brown	0.3	soft
30	mud	brown	0.5	soft
31	mud	brown	0.5	soft
32	mud	brown	0.2	soft (very)
33	sand	black (in patches)		soft
34				
35	mud	brown	0.2	soft
37	mud	brown	0.2	
40	mud	brown	0.2	
41	mud	brown	0.5	
45	mud	black	0	sloppy
46	mud	brown	0.1	soft (very)
48	mud	brown	0.2	soft (very)
49	mud	black	0	soft
50	mud		2	soft
51	mud	black	0	
53	mud	brown	0.1	soft
55	mud			hard
56	mud	brown	thick	
57	mud	brown		soft
58	mud	brown	0.7	soft
60	jelly	brown	0.3	soft
62	mud	brown	0.1	soft (very)
63	mud	brown	0.1	
64	mud	brown	0.1	
65	sand (gravel)	brown	0.2	hard
66	mud	black	0	soft
71	sand (gravel)			hard
72	mud	brown	0.1	
75	muddy-sand	brown	0.2	hard
76	sand	brown	1	
79	sand (med-coarse)	brown	0.5	hard
80	sand (med-coarse)	brown	0.5	hard

Table 1 continued

Station	Other Surface Features
2	bare mud with dead shells
3	none
4	
8	
10	thick brown diatom layer
11	thick diatom/ fine algal layer
12	
15	
17	
18	brown diatoms, and dead shells
22	some fine red algae
27	smooth
28	smooth
29	smooth and bare
30	bare
31	
32	
33	few anemones
34	
35	
37	thick brown diatom layer and anemones
40	
41	brown diatoms
45	
46	dense brown diatom layer, lots of anemones
48	thick diatom cover with brown fibrous algae too
49	
50	smooth
51	
53	algae peeling off leaving black patches
55	
56	thick layer of brown diatoms and fine filamentous algae
57	
58	brown diatoms, a few anemones
60	lots of anemones, thin fimalentous brown algae under the enteromorpha
62	virtually liquid mud
63	
64	lots of anemones
65	patches of green algae and fucus amongst gravel and stones on beach
66	thick cover with algae
71	red algae, sponges, anemones and sea-squirts
72	
75	rusty coloured diatoms, occasional green weed
76	brown diatom film
79	brown diatoms
80	some diatoms and fine algal cover

Table 1 continued

Station	Sub-Surface Substrate	Sub-Surface Colour	Sub-Surface Depth (cm)	Sub-Surface Texture
2	mud	black	30	hard
3	mud	brown	10	hard
4	mud	black	30	
8	mud	grey	30	soft
10	mud	black	30	hard
11	mud	grey		
12	mud	grey/black		
15	mud	black		
17	mud	grey	30	
18	mud	grey	30	
22	mud			hard
27	mud	black/grey	15	soft
28	mud	black	30	
29	mud	black/grey	30	
30	mud	black	30	soft
31	mud	black	30	soft
32	mud	black	30	soft (very)
33	sand			soft
34				
35	mud	black	30	soft
37	mud	black	<30	
40	mud	black	30	
41	mud	grey	30	
45	mud	black	30	sloppy
46	mud	black	15	soft
48	mud	black	2	soft (very)
49	mud	black	30	soft
50	mud		30	
51	mud	black	30	
53	mud	black	30	soft
55	mud			hard
56	mud			
57	mud			
58	mud	black	5	soft
60	mud	black	10	
62	mud	black	3	soft
63	mud	black	3	
64	mud	black	2	
65	sand (gravel)	black	5	
66	mud	black	30	soft
71	sand (gravel)			hard
72	mud	black	1	
75	muddy sand	black	30	hard
76	sand	black		
79	sand (med-coarse)	black	30	hard
80	sand (med-coarse)	black	30	hard

Table 1 continued

Station	Other Sub-Surface Features
2	
3	grey-brown layer further down
4	
8	
10	
11	black layer below grey
12	
15	
17	grey spartina mud
18	
22	
27	hard black/grey mud below the soft layer
28	firm black mud below the soft layer
29	
30	
31	
32	
33	
34	
35	
37	sand below the black mud
40	sand lamellae in the mud profile
41	sand lamellae within mud profile
45	
46	firm mud below the soft layer
48	grey root-rich eroding saltmarsh clay below the black mud
49	
50	
51	
53	hard mud at knee depth
55	
56	
57	
58	hard mud below the soft layer
60	then 10 cm of muddy/sand mix and then coarse white sand below that
62	grey spartina subsoil clay below the black mud
63	grey spartina subsoil clay below the black mud
64	5-10 cm gray mud below the black and then sand below the gray mud
65	20 cm brown sand below the black sand and then china clay layer below that
66	
71	
72	15 cm of gray clay below the black mud, and sand below the gray clay
75	
76	
79	
80	

Table 1 continued

Station	Other Comments
2	half way between the channel and the reed bed
3	in the mouth of the Piddle river
4	lots of organic detritus
8	lots of dead Mya
10	lots of worm tubes
11	
12	
15	Petrol-like film on water surface
17	
18	
22	
27	
28	
29	lots of dead scrobicularia shells
30	
31	
32	worm tubes
33	the odd cockle
34	against edge of reedbed
35	
37	
40	
41	
45	totally anoxic
46	
48	
49	bait diggers nearby. Sampling location near small freshwater runoff from marsh
50	low shore near channel
51	patches of Spartina roots present on eroding saltmarsh edge
53	
55	
56	lots of quite large dimply holes in the surface
57	lots of anemones on low level flats
58	
60	
62	
63	lots of anemones
64	
65	
66	totally anoxic
71	
72	
75	some cockles (one in the arenicola square). Lots of birds feeding here
76	Arenicola sand. Site moved because map location too close to ferry
79	extensive cockle raking, patches of Corophim arenarium
80	much dug over

Table 2 Quantitative analyses by Coulter LS130 Laser Diffraction Particle Size Analyser of the surface sediment from 46 sampling stations in Poole Harbour. Samples taken in September and October 2002

Sample Site	Mean Grain Size µm	Median Grain Size µm	Mode Grain Size µm	95% Confidence Limits µm	Standard Deviation µm	Variance μm^2	Coefficient of Variation %	% <20 µm Fine Silt and Clay	% 20-63 µm Coarse Silt	% 63-125 µm Fine Sand	% >125 µm Coarse Sand	Particles >1 mm
2	11.9	14.6	29.6	1.1-132	28.7	821	241	59.2	37.5	3.3	0	-
3	12.5	13.7	13.1	1.2-134	29.4	862	235	62.2	29.8	7.2	0.8	-
4	16.9	19.7	32.4	1.4-210	44.3	1960	262	50.5	36.4	8.5	4.6	-
8	19.1	20.6	29.6	1.5-252	52.1	2720	273	49.2	33.2	9.8	7.8	-
10	17.3	19.9	35.5	1.4-221	46.2	2130	267	50.2	35.5	9.3	5.0	-
11	30.0	36.2	42.6	1.3-696	119.0	14200	398	37.2	28.9	15.0	18.9	-
12	28.5	31.0	42.6	1.4-584	105.0	10900	367	38.4	33.7	12.8	15.1	-
15	16.8	19.4	32.4	1.2-236	47.9	2290	285	50.9	34.2	9.1	5.8	-
17	17.1	18.0	29.6	1.1-255	50.7	2570	297	53.0	29.8	9.3	7.9	-
18	15.2	18.0	42.6	1.0-232	45.9	2100	303	52.6	32.8	11.3	3.3	-
22	28.5	38.9	67.2	1.2-673	115.0	13100	402	37.0	27.8	19.3	15.9	-
27	13.4	14.1	13.1	1.0-178	36.8	1350	274	61.1	28.3	5.7	4.9	-
28	13.1	15.2	32.4	1.2-143	31.3	977	239	58.1	35.3	6.6	0	-
29	13.9	14.8	13.1	1.0-187	38.4	1470	277	59.1	30.3	6.3	4.3	-
30	11.8	14.3	32.4	1.4-103	23.9	569	202	61.9	37.9	0.2	0	-
31	11.8	14.3	29.6	1.4-101	23.5	553	199	62.1	37.7	0.2	0	-
32	12.3	14.5	32.4	1.4-112	25.7	659	208	61.0	37.4	1.6	0	-
33	98.9	226.7	263.3	3.8-2580	423.0	179000	428	19.8	8.5	2.5	69.2	-
34	12.9	15.6	29.6	1.3-128	28.6	820	222	58.4	38.6	3.0	0	-
35	11.6	13.4	38.9	1.2-112	25.3	641	219	62.5	36.4	1.1	0	-
37	44.5	31.1	716.8	0.7-2730	319.0	102000	717	42.2	18.2	3.5	36.1	+ quartz grit
40	51.6	55.4	346.0	1.2-2230	301.0	90600	583	34.6	17.0	5.5	42.9	-
41	45.5	46.8	346.0	1.6-1310	207.0	42900	455	32.2	24.4	12.8	30.6	-
45	24.9	23.6	29.6	0.9-677	109.0	12000	439	46.0	26.7	9.0	18.3	-

Table 2 continued

Sample Site	Mean Grain Size µm	Median Grain Size µm	Mode Grain Size µm	95% Confidence Limits µm	Standard Deviation µm	Variance μm^2	Coefficient of Variation %	% <20 µm Fine Silt and Clay	% 20-63 µm Coarse Silt	% 63-125 µm Fine Sand	% >125 µm Coarse Sand	Particles >1 mm
46	12.1	13.5	13.1	1.5-97.9	23.1	532	190	63.8	34.6	1.6	0	-
48	20.1	20.7	38.9	1.5-270	55.5	3080	276	49.1	33.6	11.8	5.5	-
49	12.6	13.9	14.3	1.7-92.5	22.2	495	176	63.1	34.7	2.2	0	-
50	16.6	18.9	42.6	1.3-208	43.7	1910	264	51.5	33.9	11.3	3.3	-
51	22.2	22.1	15.7	1.4-343	67.5	4550	304	47.3	30.5	10.7	11.5	-
53	22.0	24.1	51.1	1.0-500	86.2	7430	392	46.4	28.2	12.2	13.2	-
55	19.7	19.6	11.9	0.9-426	74.8	5590	380	50.5	26.0	10.0	13.5	-
56	31.3	37.7	152.5	1.2-819	134.0	18000	429	38.2	23.4	15.1	23.3	+ shells
57	18.6	18.2	13.1	0.9-366	66.5	4420	358	52.5	28.9	8.1	10.5	+ shells
58	14.2	14.9	10.9	0.9-235	45.3	2050	319	57.8	28.5	7.4	6.3	+ iron oxide *
60	55.6	74.8	346.0	1.5-2050	294.0	86600	529	30.3	16.8	10.5	42.4	+ quartz grit
62	16.7	17.5	35.5	1.0-279	53.5	2870	321	53.3	30.2	9.4	7.1	+ shells
63	40.0	36.2	379.0	1.1-1420	207.0	43000	518	37.9	22.0	8.5	31.6	-
64	32.2	30.0	29.6	1.0-998	153.0	23600	476	41.1	24.1	9.5	25.3	+ shells
65	318.4	365.7	859.9	38.7-2620	614.0	377000	193	4.6	1.6	2.3	91.5	+ gravel
66	27.5	25.2	11.9	1.0-769	123.0	15100	447	44.5	25.2	8.3	22.0	-
71	160.6	360.5	654.4	4.5-5740	835.0	697000	520	17.8	6.8	3.2	72.2	+ gravel
72	34.6	39.9	56.0	1.3-951	153.0	23400	442	37.3	23.2	13.5	26.0	-
75	65.3	197.6	240.4	1.8-2380	344.0	118000	527	32.6	4.6	0	62.8	-
76	214.8	273.3	263.3	27.6-1670	397.0	158000	185	6.1	2.2	2.4	89.3	+ quartz grit
79	181.1	219.9	219.4	30.9-1060	266.0	70500	147	5.5	1.4	1.3	91.8	-
80	306.3	375.1	415.1	55.1-1700	428.0	183000	140	3.6	1.7	1.1	93.6	+ quartz grit, small stones

* from old worm burrows

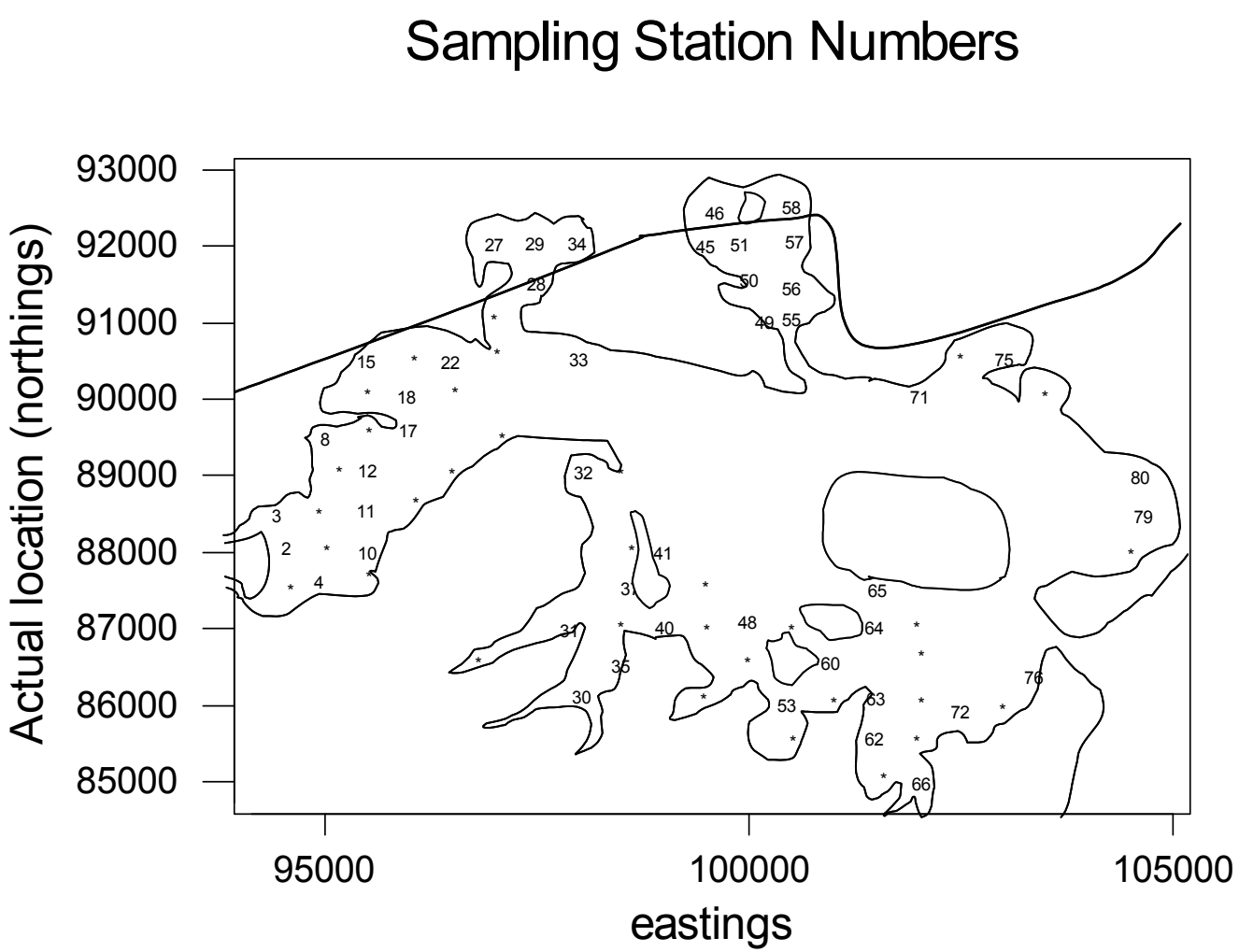

Figure 1 Grid plot of the actual locations of the 46 sediment-sampling stations (numbered). The locations of the other 34 sampling stations that comprised the rest of the harbour-wide survey of invertebrate distribution (for English Nature) are shown with asterisks. A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

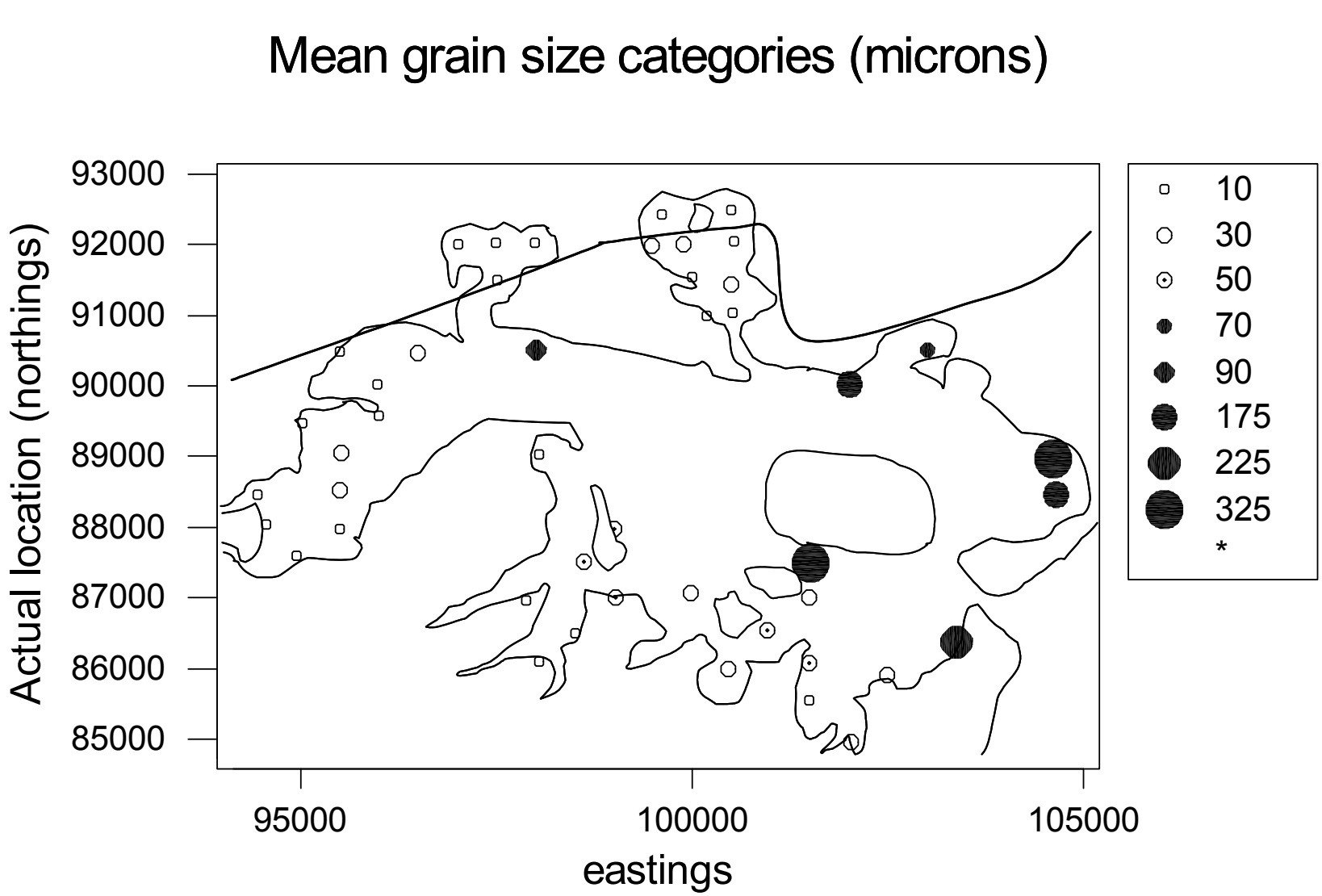

Figure 2 Grid plot of the actual locations of the 46 sediment sampling stations showing the mean grain size (microns) at each station in one of 8 categories: 10 (0-20), 30 (20-40), 50 (40-60), 70 (60-80), 90 (80-100), 175 (150-200), 225 (200-250) and 325 (300-350). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

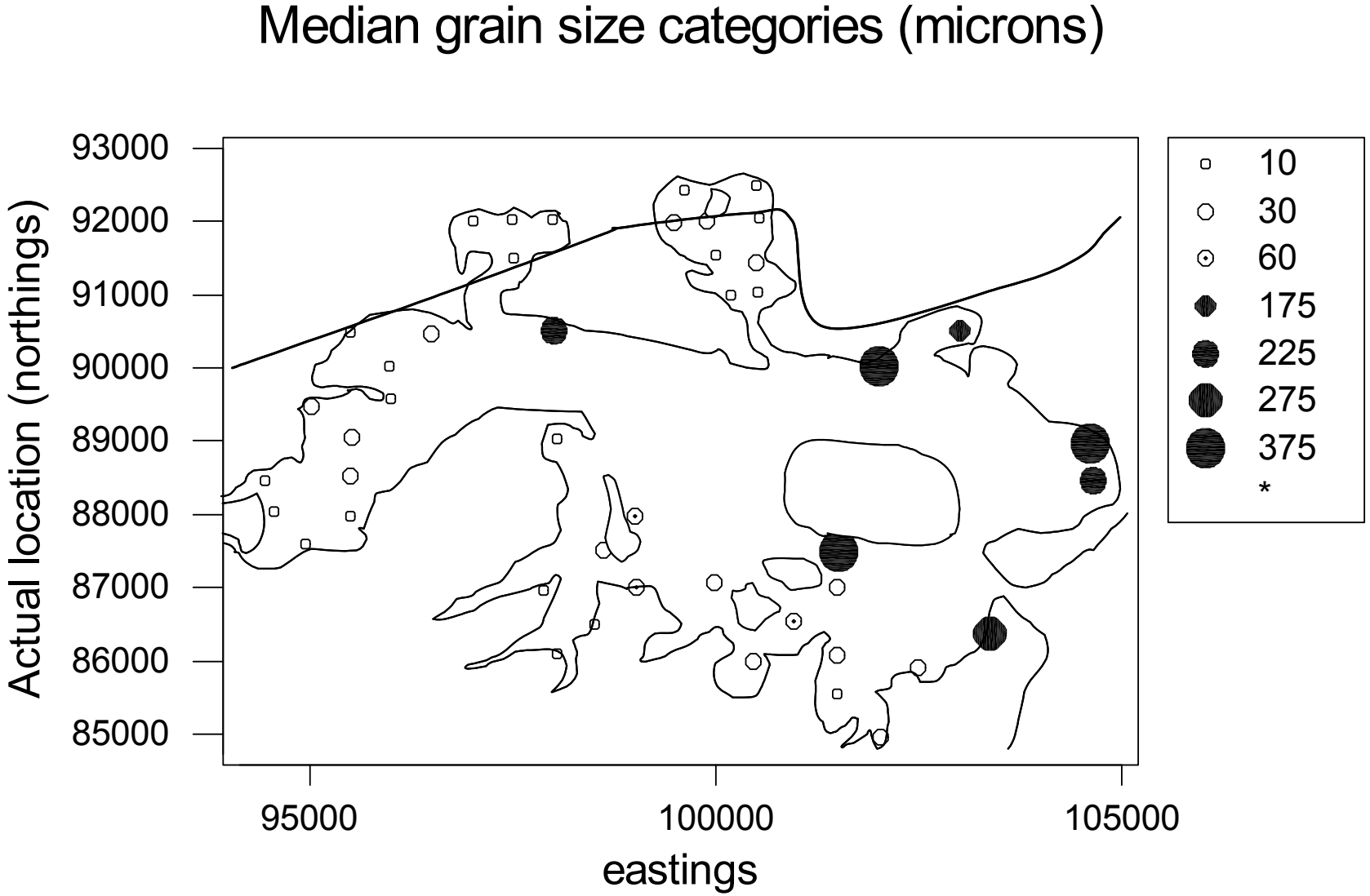

Figure 3 Grid plot of the actual locations of the 46 sediment sampling stations showing the median grain size (microns) at each station in one of 7 categories: 10 (0-20), 30 (20-40), 60 (40-80), 175 (150-200), 225 (200-250), 275 (250-300) and 375 (350-400). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

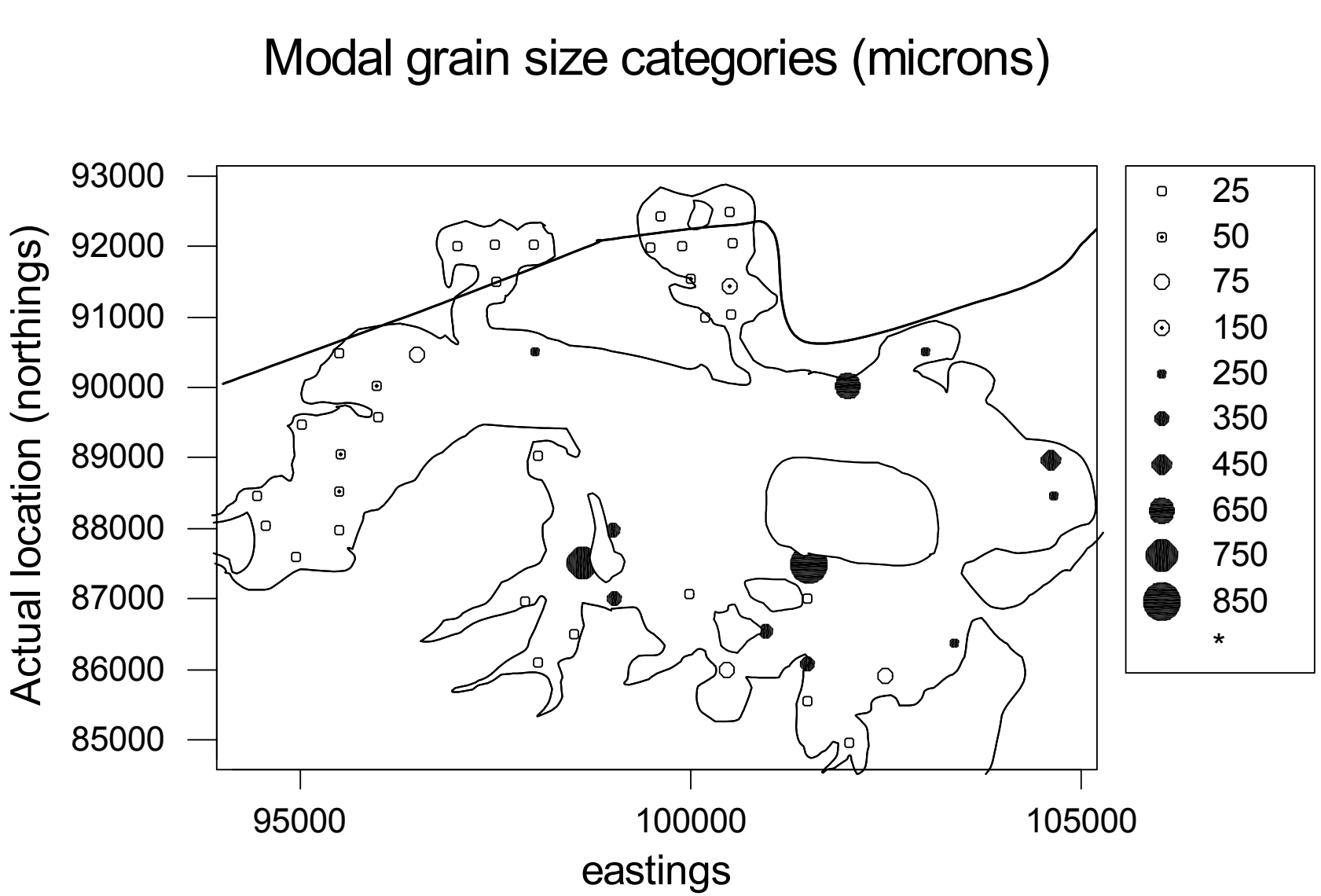

Figure 4 Grid plot of the actual locations of the 46 sediment sampling stations showing the modal grain size (microns) at each station in one of 10 categories: 25 (10-40), 50 (40-50), 75 (50-100), 150 (100-200), 250 (200-300), 350 (300-400), 450 (400-500), 650 (600-700), 750 (700-800) and 850 (800-900). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

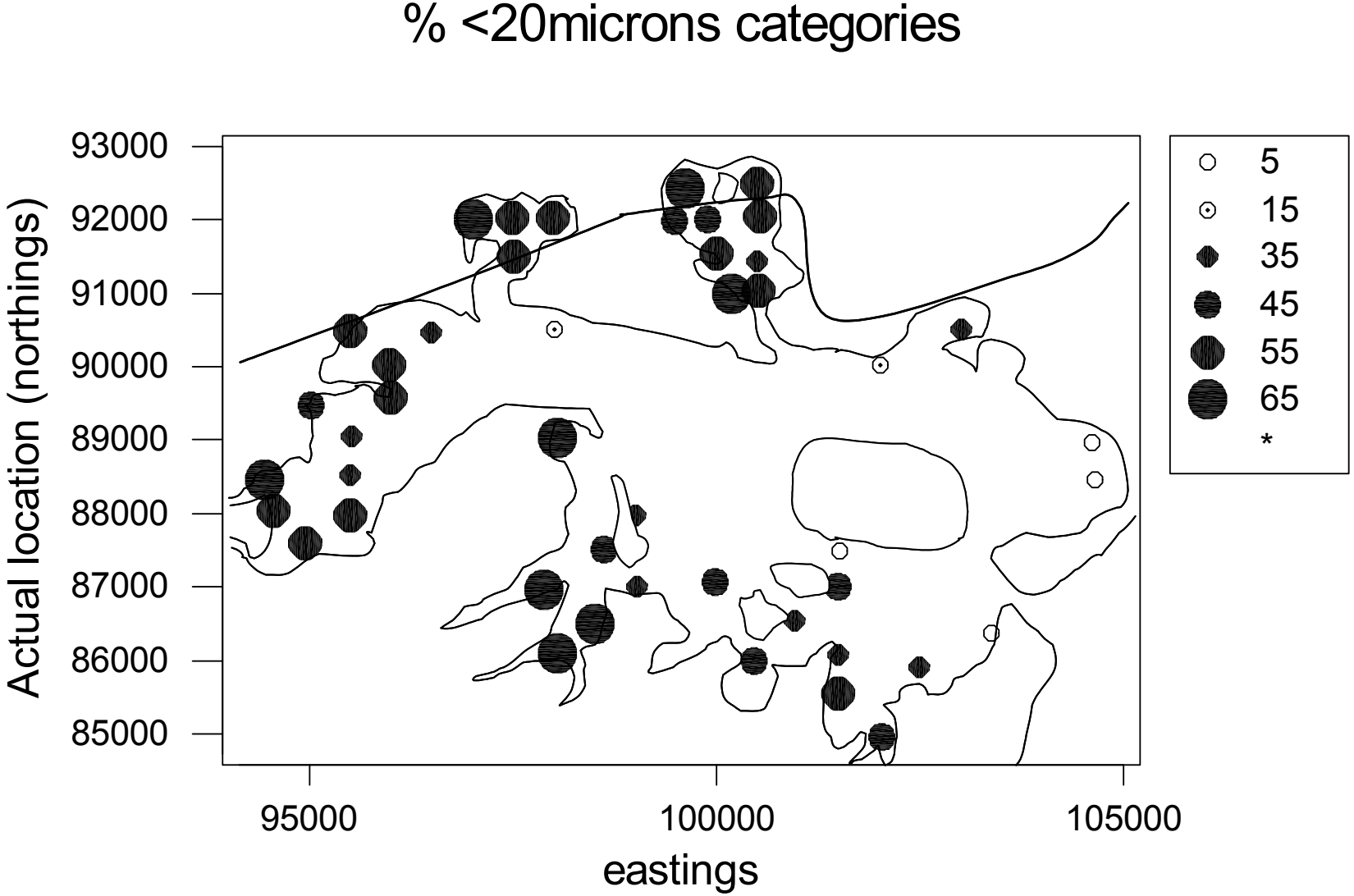

Figure 5 Grid plot of the actual locations of the 46 sediment sampling stations showing the % particles with diameter <20 microns at each station in one of 6 categories: 5 (0-10%), 15 (10-20%), 35 (30-40%), 45 (40-50%), 55 (50-60%) and 65 (60-70%). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

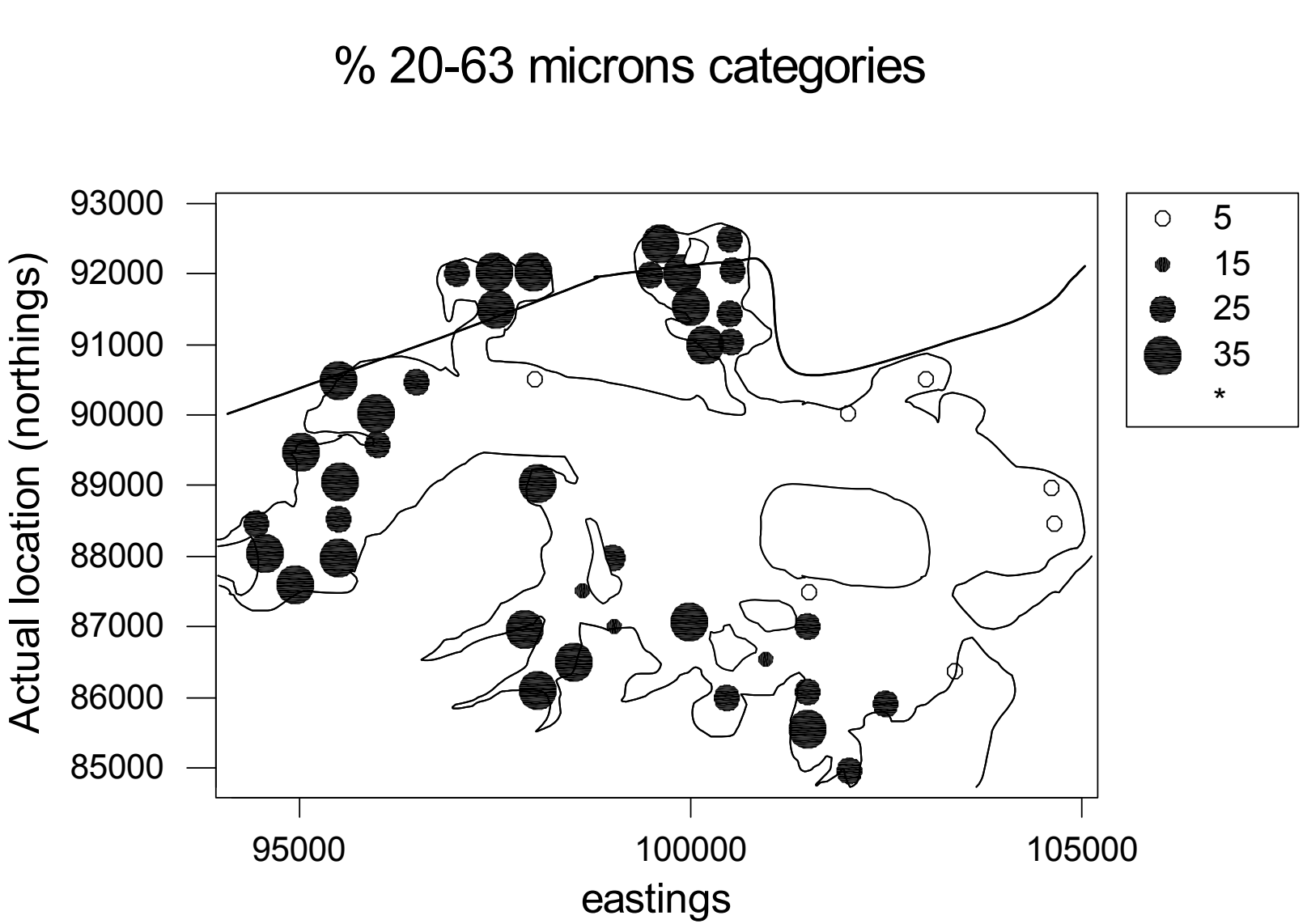

Figure 6 Grid plot of the actual locations of the 46 sediment sampling stations showing the % particles with diameter 20-63 microns at each station in one of 4 categories: 5 (0-10%), 15 (10-20%), 25 (20-30%) and 35 (30-40%). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

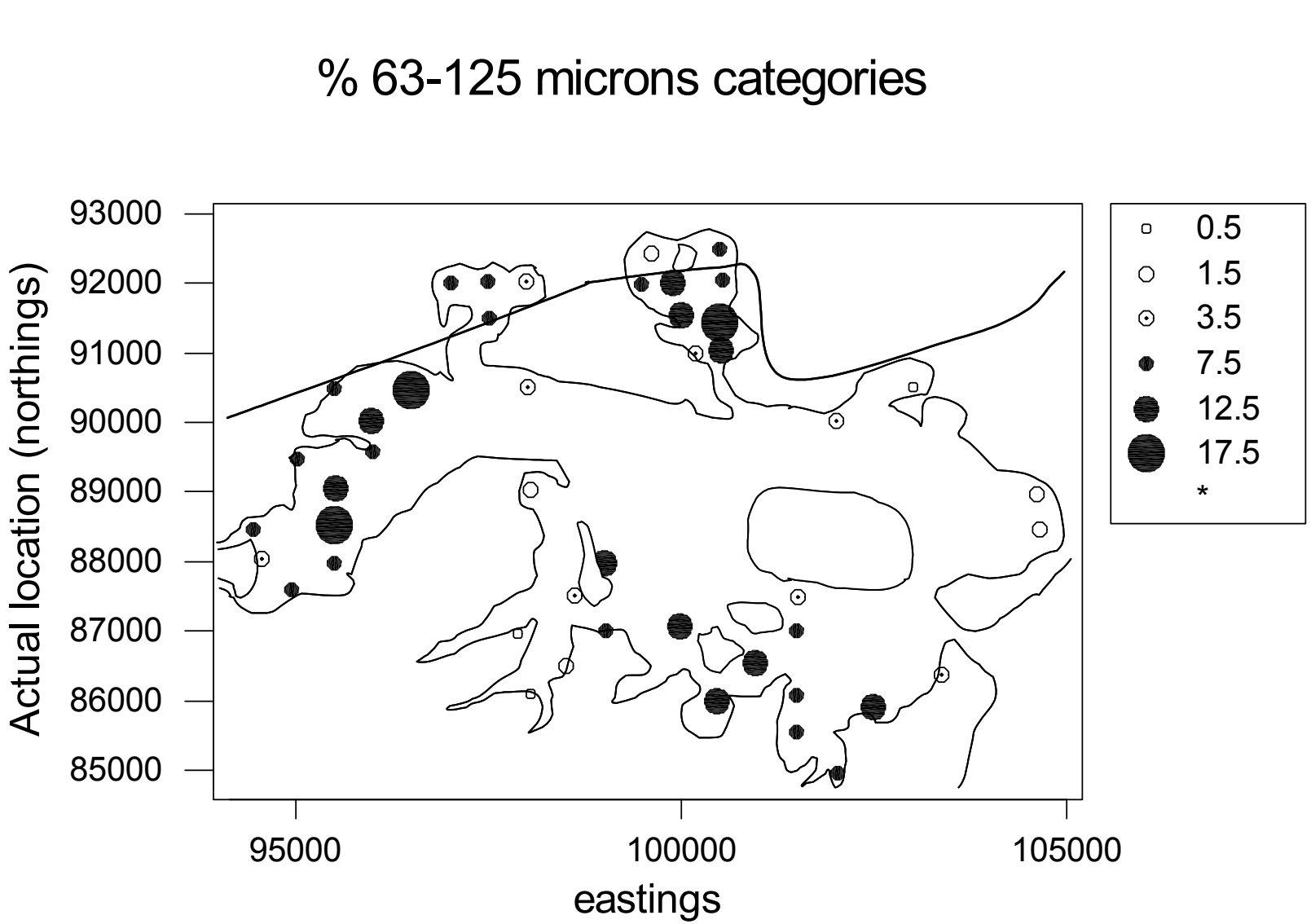

Figure 7 Grid plot of the actual locations of the 46 sediment sampling stations showing the % particles with diameter 63-125 microns at each station in one of 6 categories: 0.5 (0-1%), 1.5 (1-2%), 3.5 (2-5%), 7.5 (5-10%), 12.5 (10-15%) and 17.5 (15-20%). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

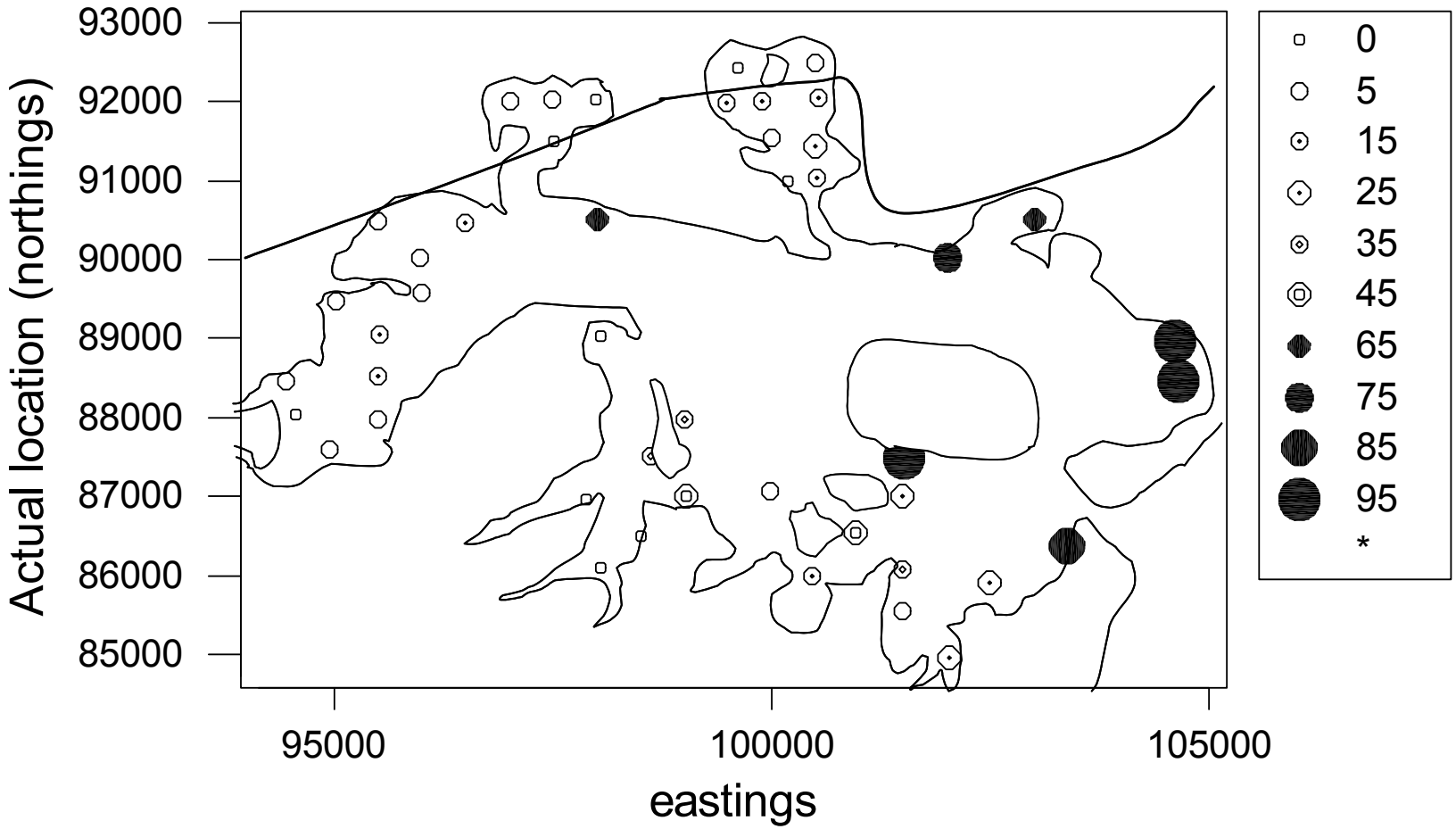

Figure 8 Grid plot of the actual locations of the 46 sediment sampling stations showing the % particles with diameter >125 microns at each station in one of 10 categories: 0 (0%), 5 (0-10%), 15 (10-20%), 25 (20-30%), 35 (30-40%), 45 (40-50%), 65 (60-70%), 75 (70-80%), 85 (80-90%) and 95 (90-100%). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

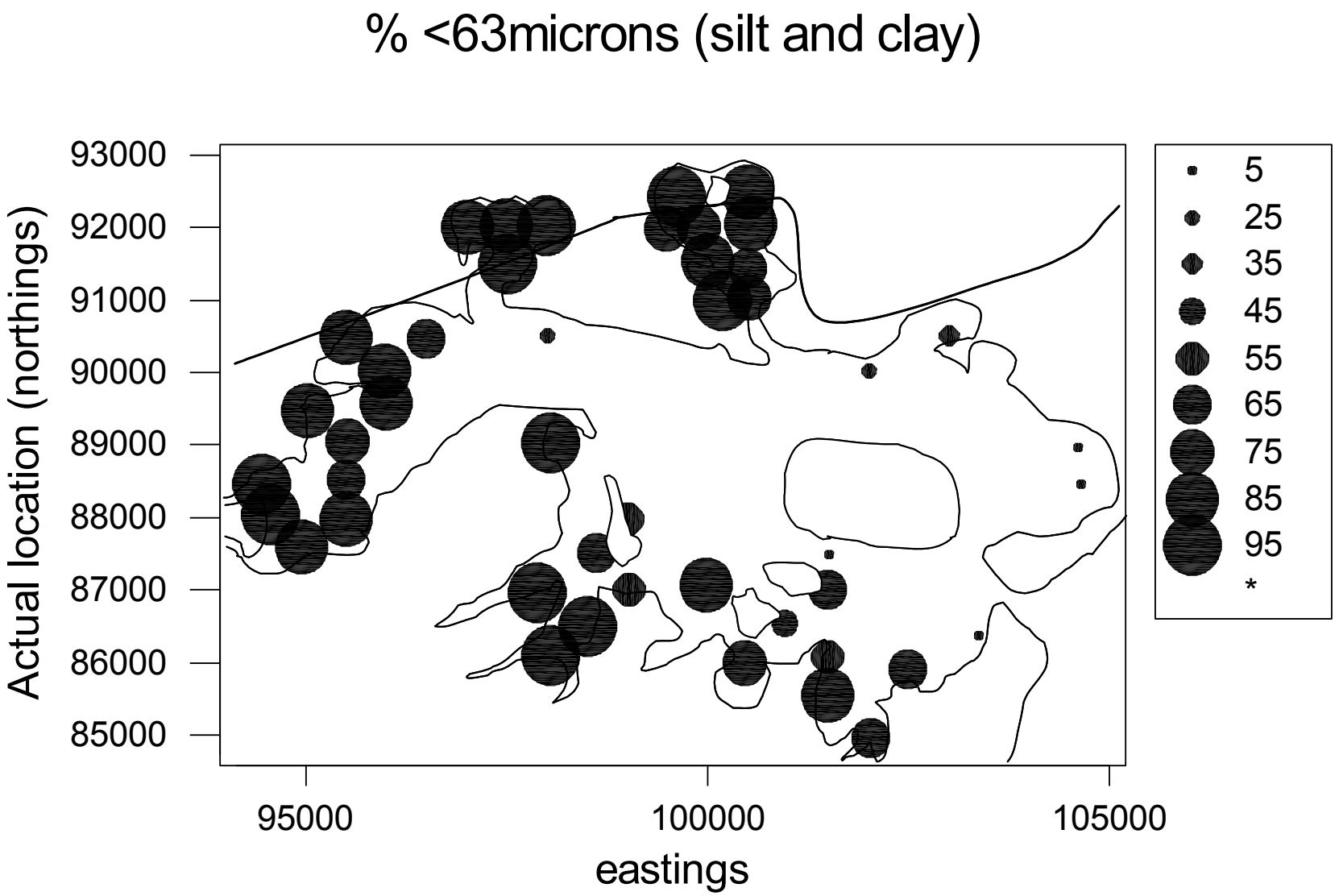

Figure 9 Grid plot of the actual locations of the 46 sediment sampling stations showing the % particles with diameter <63 microns at each station in one of 9 categories: 5 (0-10%), 25 (20-30%), 35 (30-40%), 45 (40-50%), 55 (50-60%), 65 (60-70%), 75 (70-80%), 85 (80-90%) and 95 (90-100%). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

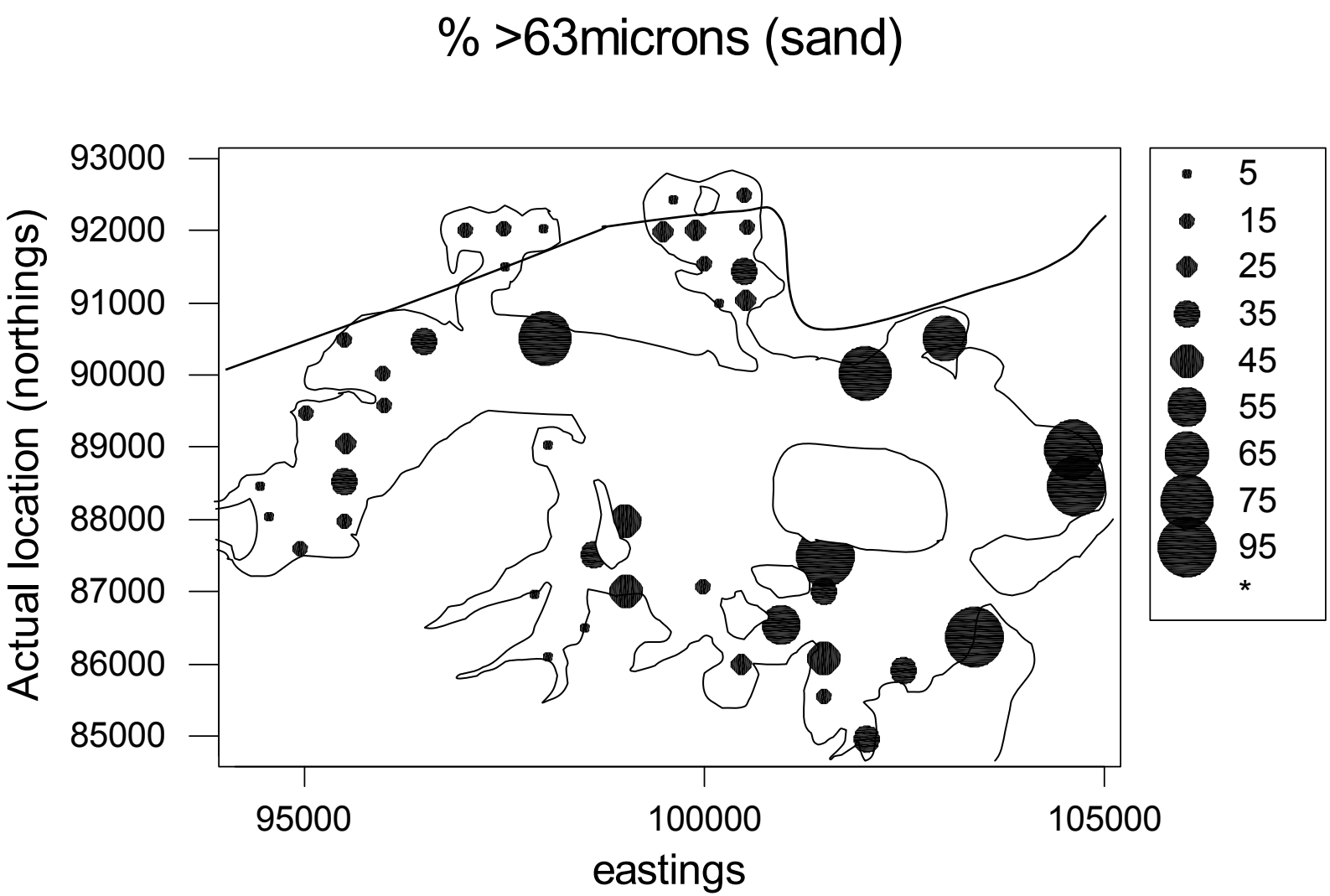

Figure 10 Grid plot of the actual locations of the 46 sediment sampling stations showing the % particles with diameter >63 microns at each station in one of 9 categories: 5 (0-10%), 15 (10-20%), 25 (20-30%), 35 (30-40%), 45 (40-50%), 55 (50-60%), 65 (60-70%), 75 (70-80%) and 95 (90-100%). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes

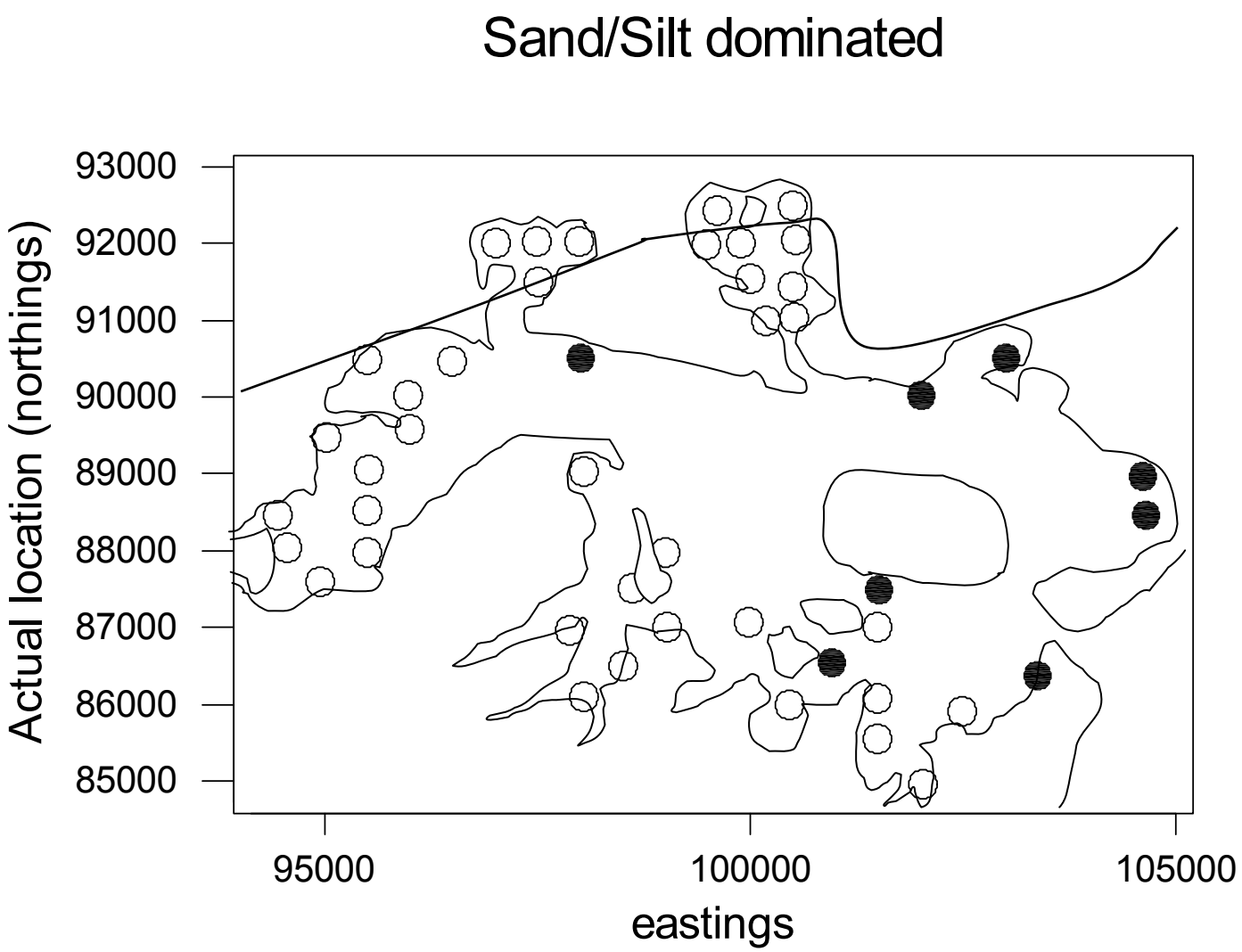

Figure 11 Grid plot of the actual locations of the 46 sediment sampling stations showing whether the surface sediment at the station was dominated (>50% of the particles) by silt and clay particles (<63 microns) (open circles) or by sand particles (>63 microns) (filled circles). A sketch outline of Poole Harbour has been superimposed on this plot to illustrate the location of each sampling station. NB this map is not to scale and purely for illustrative purposes