The Ecology of Poole Harbour
John Humphreys and Vincent May (editors)

19. Sediment Quality and Benthic Invertebrates in Holes Bay

Fiona Bowles[1] and Paul English[2]

[1]Wessex Water, Claverton Down Road, Bath, BA2 7WW

[2]Emu Ltd, 1 Mill Court, The Sawmills, Durley, Southampton S032 2EJ

This chapter presents summary comparisons between two sets of physical, chemical and biological data collected in 1991 by the Environment Agency and in 2002 by the Centre for Ecology and Hydrology. Changes in the invertebrate data have been assessed in the context of natural variation and in relation to the present physical and chemical conditions.

Introduction

Poole Sewage Treatment Works serves a population equivalent of over 150,000 with inputs from domestic, tourism and local industry sources. The works is located on Cabot Lane and discharges to Holes Bay at SZ 00710 93560. The works, which has been present since 1922, has two streams. The western stream was developed in 1957–61 and the eastern stream was added in 1969–74. Both are activated sludge. In 1994, a new inlet works was added and in 1996, a biological aerated filter replaced the old eastern stream. Under the Urban Wastewater Treatment Directive, Poole Works was required to have ultra violet disinfection added by March 2003 to ensure bathing water and shellfish water quality for Poole Harbour and its beaches.

In order to ensure effective disinfection, additional settlement of suspended solids in the treated effluent was required. Ferric sulphate is the proposed flocculent, although the discharge consent will permit the use of an aluminium salt if the UV performance deteriorates. As there is no current environmental quality standard for aluminium in the marine environment, the freshwater standard of 1 mg l^{-1} aluminium was assumed and English Nature requested that a baseline survey of the biota and metal levels be established in Holes Bay. Wessex Water, part of the Poole Harbour Steering Group, therefore, contracted the Centre for Ecology and Hydrology to extend their survey of prey distribution in Poole Harbour to collect:

- additional invertebrate samples in Holes Bay
- sediment samples for analysis of particle size, carbon, nitrogen and metal parameters
- samples of a numerous bivalve, the Edible Cockle C*erastoderma edule*, for tissue analysis of metal parameters.

In order to gain comparative data, the sample sites chosen were among those that had been previously sampled by the Environment Agency in 1991 and 1996 and are illustrated in Figure 1. Richard Caldow and colleagues from the Centre for Ecology and Hydrology conducted the survey. Chemical samples were analysed by the Environment Agency (Starcross Laboratory). Paul English of Emu Ltd, Southampton, was commissioned to compare the available ecological data for 1991 and 2002 and to assess current sediment quality with respect to the potential effects on the local bird feeding/sediment invertebrate interest.

Methodology

Ten sites were selected from 46 previously sampled locations (shown in Figure 1) and located with hand-held GPS. The methodology for benthic invertebrate and sediment samples was as for the Poole Harbour bird prey survey (see chapter 7). In addition, at each of the sites, 500 ml of the surface sediment (maximum depth 1 cm and avoiding black anoxic material if possible) was collected for metal (As, Cd, Cr, Cu, Pb, Ni, Zn, Fe, Hg and Al), carbon and nitrogen analysis, with a duplicate sample being collected at five of the sites. In addition, at six sites (1, 3, 4, 5, 17 and 28), 30 cockles were caught in hand-held dredging nets and depurated for 72 hours in clean seawater prior to being frozen and sent for tissue analysis.

Results and discussion

Particle size analysis and organic ratios

Fine sediment, except at the outermost site (46), dominated the sediment. Since 1991, a slight coarsening of the sediments is evident with all stations showing an increased fine sand component, particularly the lower mudflat stations (Stations 1, 17, 28 and 34), where some of the greatest changes in cirratulid numbers have also occurred. The bay has become less muddy.

Ratios of organic carbon to organic nitrogen of 10:1 to 15:1 and 11:1 to 16:1 were found in 1991 and 2002, respectively. Values of 7:1–12:1 are typical of shallow marine sediments but estuarine sediment usually exhibits higher ratios, as a result of high organic carbon inputs from fringing plant communities or riverine inputs (Murray *et al.*, 1980). Sewage influence would lead to a lower ratio due to the input of nitrogenous compounds. The carbon:nitrogen ratios are typical of estuarine sediments and indicate a dominant, natural terrestrial source with no significant influences from the outfall.

Metals

The sediment comparison is shown in Table 1. Sediment concentrations of iron and arsenic have significantly decreased ($P<0.05$) over the 11 year period between 1991 and 2002, whilst aluminium levels have significantly increased ($P<0.05$). All sampling stations returned raised aluminium levels with the most notable at Station 6, adjacent to the outfall

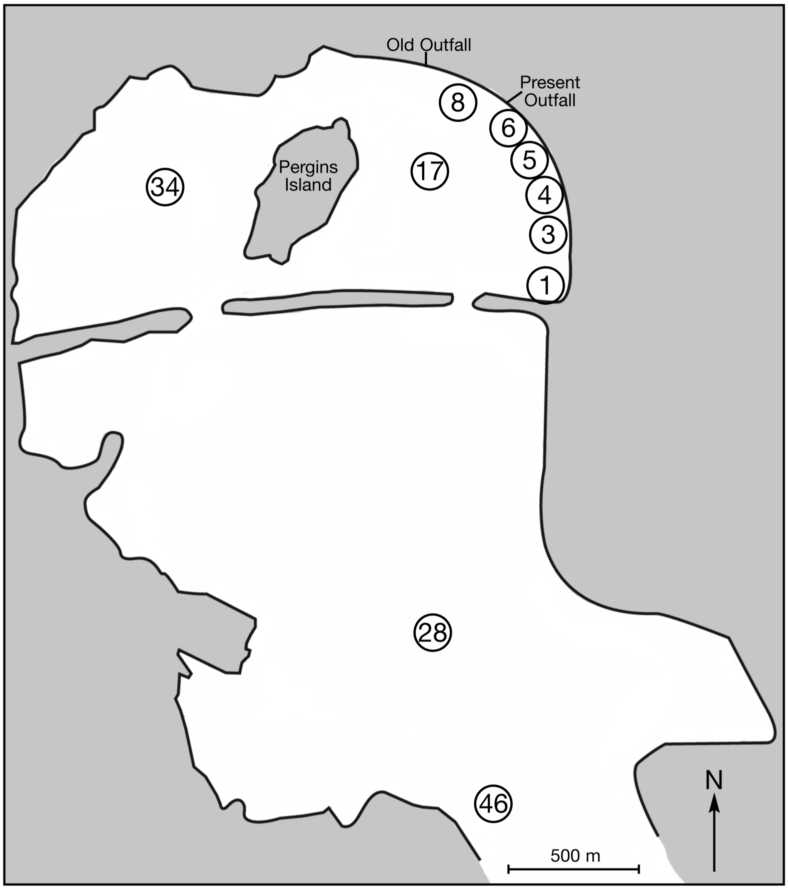

Figure 1 Holes Bay showing the sampling stations. (Station numbers relate to original surveys in the 1990s

(+28.2%), Station 28 downstream (+32.6%), and Station 34 (+30.8%), on the western side of the bay. The metal levels did not appear to relate to the invertebrate populations.

When corrected to 1% organic carbon, the present metal levels are all below the UK proposed tentative action levels (CEFAS, 1997) and the US-developed thresholds (Zarba, 1989), where available (Table 2). There is no specific toxicity data available relating to aluminium and the fauna distribution did not show any significant adverse effect from the sediment quality.

The cockle tissue data form a baseline for any future changes and no comparison with historic levels was possible.

Table 1 Statistical comparison between sediment chemical determinands

Station	Fe 1991 (mg kg⁻¹)	Fe 2002 (mg kg⁻¹)	Al 1991 (mg kg⁻¹)	Al 2002 (mg kg⁻¹)	As 1991 (mg kg⁻¹)	As 2002 (mg kg⁻¹)	Org C 1991 (%)	Org C 2002 (%)	Org N 1991 (%)	Org N 2002 (%)
1	32300	23900	9410	11400	14.60	11.00	3.08	2.95	0.30	0.22
3	39300	25100	13400	14100	14.50	11.00	3.48	3.62	0.35	0.27
4	35200	24800	11500	12950	10.20	11.50	3.39	3.71	0.33	0.23
5	35100	23700	10700	12100	14.60	11.00	3.61	3.88	0.35	0.28
6	28300	27150	8940	12450	10.30	12.50	3.76	4.94	0.35	0.41
8	37600	27150	12100	12550	15.80	12.00	3.92	5.01	0.33	0.41
17	36000	20200	10800	10600	10.10	9.00	3.22	3.73	0.32	0.29
28	21800	20000	6620	9820	12.90	9.00	1.62	3.68	0.11	0.35
34	30200	24350	8340	12050	16.10	12.00	2.26	3.73	0.20	0.37
46	27600	19150	10400	11400	15.50	11.00	2.59	1.05	0.24	0.07
average	**32340**	**23550**	**10221**	**11942**	**13.46**	**11.00**	**3.09**	**3.63**	**0.29**	**0.29**
var	**28862667**	**8206111**	**3852588**	**1469862**	**5.83**	**1.39**	**0.53**	**1.21**	**0.01**	**0.01**
	Log	Log	Log	Log						
	4.51	4.38	3.97	4.06						
	4.59	4.40	4.13	4.15						
	4.55	4.39	4.06	4.11						
	4.55	4.37	4.03	4.08						
	4.45	4.43	3.95	4.10						
	4.58	4.43	4.08	4.10						
	4.56	4.31	4.03	4.03						
	4.34	4.30	3.82	3.99						
	4.48	4.39	3.92	4.08						
	4.44	4.28	4.02	4.06						
average	**4.50**	**4.37**	**4.00**	**4.08**						
var	**0.01**	**0.003**	**0.01**	**0.00**						
f test	**0.30**		**0.05**		**0.04**		**0.24**		**0.46**	
t test	***P*<0.05**		***P*<0.05**		***P*<0.05**		***P*>0.05**		***P*>0.05**	

Invertebrate populations

The benthic populations were consistent with the Joint Nature Conservancy Committee (JNCC) biotope classifications LMU.HedOl on upper shore areas and LMU.HedStr on mid to lower intertidal zones and are typical of sheltered sandy mud – mud and reduced salinity conditions (Connor *et al.*, 1997).

Over 30 species of invertebrates were recovered in 2002, the dominant species being the ragworm *Hediste diversicolor* with *Hydrobia ulvae*, *Cirratulus fliformis* and *Malacocerus fugilinosus*. The 1991 and 2002 top ranking species are compared in Table 3. Ragworms appear to have reduced throughout Holes Bay, while tubificid worms have declined in abundance particularly at Stations 5 and 6 adjacent to the sewage outfall. The spionid worm *Streblospio shrubsolii* has been replaced by *Malacocerus fuliginosus* throughout and by cirritulid worms at the lower mudflat sites. This change correlates with changes in sediment but it is unclear whether this caused it.

Mud Shrimp *Corophium volutator* abundance declined from an average of 771 m^{-2} to 25 m^{-2} in 2002. However, this may be a reflection of its patchy distribution or of localized salinity changes, for example, at Station 1. It is still present at Station 34 on the western side (212 m^{-2}).

Multivariate analysis of the biological data suggests that there were differences in the abundance of characteristic mudflat species, including ragworms, tubificid worms and total spionid worms between 1991 and 2002. However, these differences may be within the expected natural variation or within the variation resulting from the methodological differences, e.g.

- changes over an 11 year period due to natural climatic variations or anthropogenic pressures, such as sediment disturbance
- seasonal difference in the timings of the 1991 (June) and 2002 (September) surveys
- different biological sampling methods employed in 1991 and 2002.

In conclusion, Holes Bay remains biologically, physically and chemically within the range of normal estuarine conditions. No significant adverse effects on the infauna could be attributed to the metal levels. Continued coarsening of the sediments may be having a more pronounced effect on the invertebrate populations in the bay and hence the bird prey availability.

Analysis of the treated effluent annual average shows an increase from 0.04 mg l^{-1} in 1996 to 0.17 mg l^{-1} aluminium. Its source is, however, the incoming sewage itself rather than any dosing. Annual averages for iron levels have varied without an obvious trend from 0.34 g l^{-1} to 0.84 g l^{-1} since 1995. The consented use of iron or aluminium flocculent from 2003 is considered unlikely to impact on the infauna because:

Table 2 Comparison of sediment quality with metals quality guidelines

Determinand	MAFF (DEFRA) action levels (mg kg^{-1})	US-developed threshold (mg kg^{-1})	Holes Bay 2002 mean concentrations (mg kg^{-1}) (corrected to 1% OC)
Aluminium	N/d	N/d	3295.9
Iron	N/d	N/d	6499.5
Arsenic	8	33	3.0
Lead	40	132	19.5
Nickel	100	20	5.9
Copper	40	136	14.2
Chromium	100	25	10.8
Zinc	200	760	58.8
Cadmium	2	31	0.3
Manganese	N/d	N/d	45.0
Mercury	0.4	0.8	0.20

N/d=no data.

Table 3 Top ranking macro-invertebrates for 1991 and 2002 sampling occasions

1991			2002		
Taxa	**Mean abundance (m^2)**	**No. stations present (10)***	**Taxa**	**Mean abundance (m^2)**	**No. stations present (10)***
Hediste diversicolor	2843	10	*Hediste diversicolor*	1630	8
Tubificidae	1218	9	*Hydrobia ulvae*	1427	10
Corophium volutator	771	8	Cirratulidae	1317	6
Total spionids	433	10	Total spionids	1151	9
Streblospio shrubsolii	430	10	*Malacocerus fuliginosus*	1130	9
Abra tenuis	408	9	Tubificidae	614	8
Hydrobia ulvae	154	8	*Cyathura carinata*	445	9
Cyathura carinata	30	3	*Abra tenuis*	398	7
Actiniaria spp.	15	1	*Actiniaria* spp.	292	3
Terebellida	15	1	*Terebellida*	123	2

*Number of sample stations.

- the incoming metals are largely associated with sludge in sewage treatment so the additional metal flocculent will increase metal removal from the effluent, such that discharge levels should remain less than 50% of the incoming effluent (absolute consent limits are 3 mg l^{-1} of iron or 5 mg l^{-1} of aluminium)
- the species currently predominant in the upper mudflat, close to the sewage discharge, are ragworms, tubificids and spionids, which are tolerant to disturbance and pollution (Pearson and Rosenberg, 1978).

Acknowledgements

This chapter reflects the views of the authors and is not a necessarily the view of Wessex Water Services Ltd. Thanks are owed to Nicole Price of the Environment Agency, Blandford, for arranging depuration of bivalve samples prior to analysis.

References

CEFAS (1997) Marine Pollution Monitoring Group. Final Reports of the Metals Task Team and the Organics Task Team. *Aquatic Environmental Monitoring Report*. Lowestoft: CEFAS.

Connor, D. W., Brazier, D. P., Hill, T. O. and Northern, K. O. (1997) *Marine Nature Conservation Review: Marine Biotope Classification for Britain and Ireland* Volume 1. *Littoral Biotopes*. Version 97.06 JNCC Report, No 229. Peterborough: Joint Nature Conservancy Committee.

English, P. (2003) Holes Bay Intertidal Ecological Data Review and Assessment. Report for Wessex Water. November 2003 (in draft).

Murray, L. A., Norton, M. G., Nunny, R. S. and Rolf, M. S. (1980) The field assessment of dumping wastes at sea: 6. The disposal of sewage sludge and industrial waste off the River Humber. *Fisheries Research Technical Report*, No. 55. Lowestoft: Ministry of Agriculture, Fisheries and Food.

Pearson, T. H. and Rosenberg, R. (1978) Macroinvertebrate succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Review*, **16**: 229–311.

Zarba, C. (1989) *National Perspective on Sediment Quality.* Committee on Contaminated Sediments – Assessment and Remediation (ed.). Washington DC: National Academy Press.