

Introduction

Contamination of the estuarine/coastal environment arising from continuous sewage discharges may only produce intermittently detectable effects in shellfish monitoring programmes due to the interaction of tides, currents, wind and other variables on the discharge plume. A number of studies have looked at the effect of meteorological and environmental factors on water quality, principally with respect to bathing waters. Currents influenced by tidal state and wind have been determined as having a large impact (Smith, *et al.*, 1999). Some studies have also looked at the effect of a limited number of factors on the microbiological contamination of shellfisheries: these have shown significant effects of season, tidal state and rainfall (Brock, Galbraith and Benseman 1985; Wood 1955).

Objective

The present work was undertaken to investigate the significance of a range of environmental factors on the microbiological contamination of shellfish beds, as determined by *E. coli* concentration in the shellfish, and variation in such effects between and within different harvesting areas. The object was to identify whether such factors need to be taken into account when assessing the potential effects of proposed sewage discharges on commercial shellfisheries.

Selection of study areas

Three areas (A, B and C) containing active commercial shellfisheries were selected from those in England and Wales on the basis of differing topographical and hydrographical characteristics (See Figure 1). Three monitoring points were selected in each area. The shellfish present in all 3 areas were native oysters (*Ostrea edulis*) which lay below the low water mark and were normally harvested by dredging. The main sewage discharge in area C was upgraded from crude to secondary treatment in spring 1997 and data were available both pre- and post-improvement.



Figure 1: Study areas selected for the analyses

Data

- *E. coli* testing of shellfish from commercial shellfisheries was undertaken on an approximately monthly basis using a standard method (MAFF, DoH & PHLS, 1992)
- Tidal data for the times of sampling were determined using Tidecalc (Hydrographic Office, Taunton, England) using the nearest standard port for each location.
- Meteorological data were obtained from the UK Meteorological Office (Bracknell, England).
 - o Rainfall data was amalgamated to produce totals over the two days prior to sampling.
 - o The predominant wind direction and speed over the 24 hours prior to sampling was determined by vector averaging of the hourly data.
- Data were converted into categorical variables (factors) by assigning values to one of four groups (as shown on the x-axes of Figures 2-5).
- General linear modelling and preparation of graphs were undertaken in Minitab version 13 (Minitab Inc., State College, USA). Generalized linear modelling was undertaken in Genstat for Windows, 5th edition (NAG Ltd, Oxford, UK).

Figure 2: Main effects plots for Area A on the East Coast of England

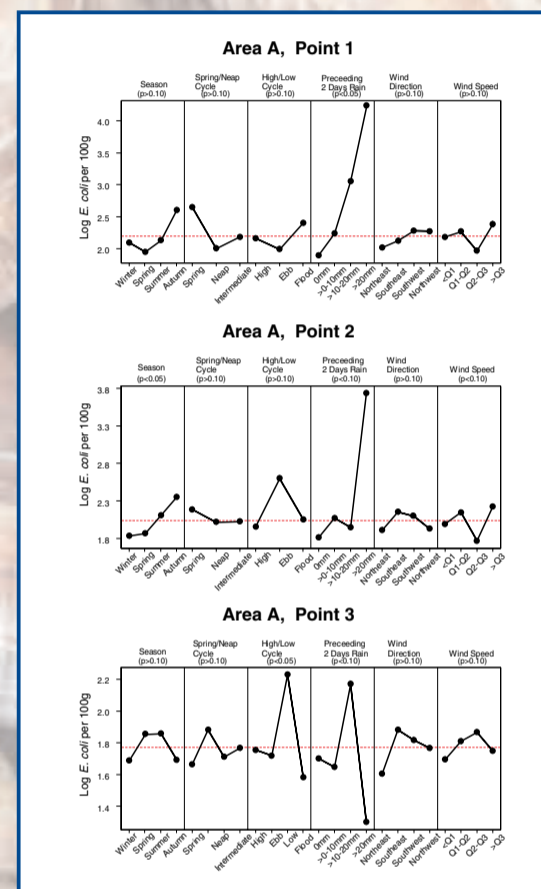


Figure 3: Main effects plots for Area B on the South West Coast of England

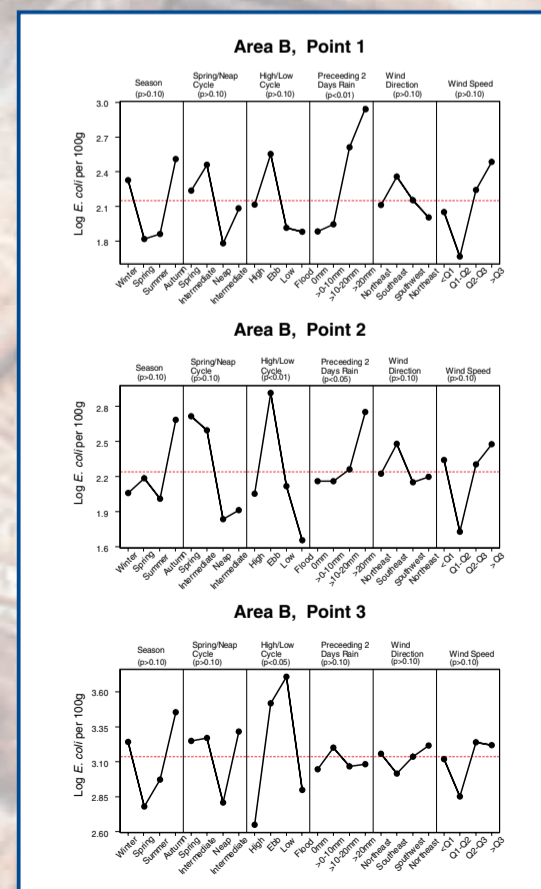


Figure 4: Main effects plots for Area C on the South Coast of England: Pre-improvements

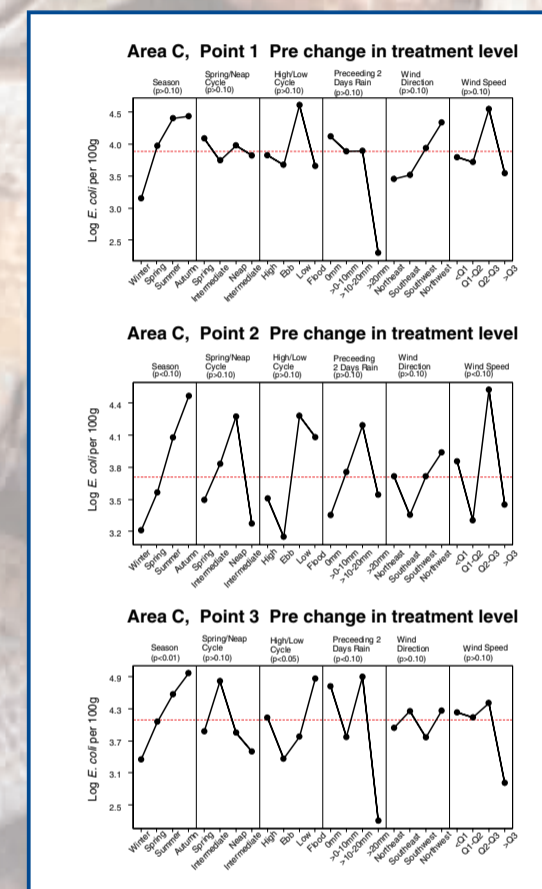
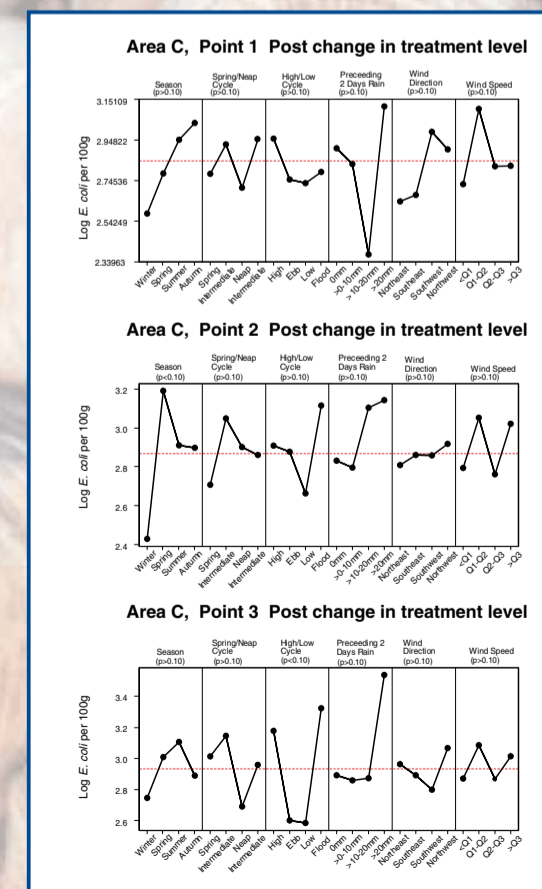


Figure 5: Main effects plots for Area C on the South Coast of England: Post-improvements



Results and discussion

The main effects plots (which show mean log *E. coli* concentrations) are shown in Figures 2-5 for areas A, B, C pre-improvements and C post-improvements respectively. The associated accumulated probability values obtained from general linear modelling are shown above each plot. These show that environmental factors may significantly affect the contamination of shellfisheries as indicated by the concentration of *E. coli*. The factors that were shown to be of most significance were season, tide (both spring/neap and high/low cycles) and rainfall on the days prior to sampling. The effects varied between the study areas and between sample points within individual areas. It was not possible to undertake analysis of interactions due to the unbalanced nature of the data sets.

Diagnostic plots showed lower variability of residuals at very low fitted values ($\log_{10} E. coli \leq 1.6$) for some of the sample points. This effect was reduced by:

- eliminating the wind factors
- using generalized linear modelling with a gamma distribution (data not shown).

However, the accumulated probabilities for the other factors were similar by all methods.

Conclusions

A number of environmental factors were shown to affect the extent of contamination detected in shellfish. Such analyses may contribute to the understanding of the nature of impacting sources when sewage improvement schemes are considered and also to the interpretation of the results from monitoring programmes. The effects were shown to be site specific and thus such analyses would need to be undertaken for each monitoring point. Much larger monitoring data sets would be required to enable analysis of the interaction of factors. The analyses performed in this study could also be applied to the analysis of putative viral indicators, such as F+coliphage and could be extended to consideration of bacterial and viral pathogens.

Acknowledgements

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References

- Brock R.L., Galbraith G.R. and Benseman B.A. (1985) Relationships of rainfall, river flow and salinity to faecal coliform levels in a mussel fishery. *New Zealand Journal of Marine and Freshwater Research* 19, 485-494.
- MAFF, DoH and PHLS Working Group (1992) Bacteriological examination of shellfish. PHLS Microbiology Digest, 9, 76 - 82.
- Smith P., Carroll C., Wilkins B., Johnson P., Gabhainn S.N. and Smith L.P. (1999) The effect of wind speed and direction on the distribution of sewage-associated bacteria. *Letters in Applied Microbiology* 28, 184-188.
- Wood P.C. (1955) Factors affecting the pollution and self-purification of molluscan shellfish in a polluted estuary. *International Council for the Exploration of the Sea, Shellfish Committee No. 23*, 1-8.