

A comparison of salmonella serotypes found in the faeces of gulls feeding at a sewage works with serotypes present in the sewage

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SUMMARY

The numbers of salmonella serotypes in raw sewage, sewage sludge and final effluent at a sewage treatment works were determined. Resting gulls which had previously been feeding on the sewage were disturbed and individual faecal samples tested for the presence of salmonellae. The serotypes were compared with those in the sewage. Six serotypes were isolated from the sewage, *Salmonella stanley* being found in all types of sample. Eleven of the twenty gull faeces samples were positive for salmonellae, a carriage rate of 55%. Seven serotypes were found, *S. stanley* being most frequent. Three serotypes were found in both sewage and gull faeces.

INTRODUCTION

The contamination of pasture and surface waters by gulls carrying salmonellae and the subsequent infection of livestock has been well documented (Johnston *et al.* 1981; Communicable Diseases Scotland [CDS] Weekly Report, 1981 *a*). Sewage has often been suggested as the original source of infection for the gulls. Fenlon (1981) showed that the level of carriage was highest near outfalls, the serotypes carried by the gulls being similar to those in the human population and therefore to be expected in the sewage.

This study was made, at a sewage works where gulls were known to feed and subsequently rest, in an effort to determine the doses of salmonellae to which gulls feeding on raw sewage are exposed, and also the correlation between those serotypes found in the sewage and in gull faeces.

MATERIALS AND METHODS

The sewage treatment works

The sewage works is a conventionally laid-out, activated sludge plant, shown diagrammatically in Fig. 1. It treats waste from a population of about 60000 and trade waste from a large industrial estate.

The plant is surrounded by a large, well-mown, grassed area, enclosed by a perimeter fence, this providing the gulls with an ideal secure site to rest, preen and defaecate after feeding (Hickling, 1967).

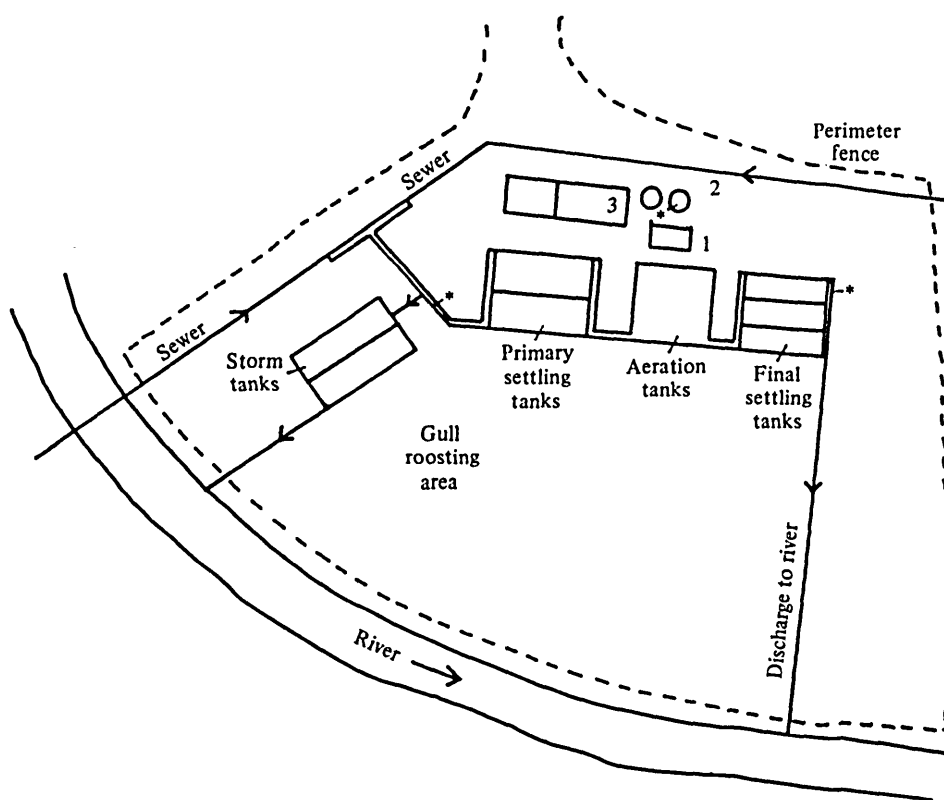


Fig. 1. Diagrammatic layout of sewage works showing sampling sites. *Sampling sites; 1, sludge storage; 2, sludge mixing; 3, sludge storage.

Sampling

Samples of raw sewage, final effluent and sewage sludge were taken from the points shown in Fig. 1.

Gull faeces were collected by disturbing the resting gulls and collecting individual droppings in sterile universal containers using sterile cotton swabs.

Counts

Numbers of salmonellae were determined on sewage samples only, using a 3 tube most probable number (MPN) technique on decimal dilutions prepared using $\frac{1}{4}$ strength Ringers solution (Standard Methods, 1967).

Salmonella isolation

Gull faeces and sewage dilutions were pre-enriched in nutrient broth for 24 h before enrichment in Muller-Kauffmann tetrathionate broth (Oxoid) and magnesium chloride/malachite green broth (Rappaport, Konforti & Vavon, 1956). Enrichment broths were plated out after 24 and 48 h on modified brilliant green agar (Oxoid).

Presumptive positive colonies were confirmed using salmonella polyvalent H agglutinating serum (Wellcome Reagents Ltd) and serotyped by the Scottish Salmonella Reference Laboratory.

Table 1. Numbers and serotypes of salmonellae in the sewage

	Salmonellae	
	Serotypes (no. of isolates)	Total nos/ml (95% confidence limits)
Raw sewage	<i>S. mbandaka</i> (5) <i>S. stanley</i> (1)	24 (3.6-130)*
Final effluent	<i>S. stanley</i> (3) <i>S. derby</i> (1)	4.3 (0.7-21)
Untreated primary sludge	<i>S. stanley</i> (1) <i>S. virchow</i> (1) <i>S. binza</i> (1) <i>S. enteritidis</i> (1) <i>S. derby</i> (1) <i>S. mbandaka</i> (1)	12 (3-38)

Table 2. Serotypes in gull faeces compared with sewage

Serotypes	No. of samples positive	Sewage sample positive
<i>S. stanley</i>	3	Raw, effluent, sludge
<i>S. typhimurium</i> (phage type 40)	2	—
<i>S. typhimurium</i> (phage type 110)	1	—
<i>S. virchow</i>	1	Sludge
<i>S. binza</i>	1	Sludge
<i>S. newport</i>	1	—
<i>S. ohio</i>	1	—
<i>S. schwarzengrund</i>	1	—

RESULTS

The results presented in Tables 1 and 2 were derived from the examination of raw sewage, final effluent, untreated sewage sludge, and gull faeces sampled on one occasion within the perimeter of the sewage works. The time of sampling was selected to coincide with a high sewage flow rate and a gull post-feeding rest period.

The results in Table 1 show that, within the wide limits of the MPN test accuracy, some reduction in salmonellae numbers occurred during treatment, but a significant proportion survived in the untreated primary sludge or were discharged in the final effluent.

The sewage samples showed a restricted number of serotypes in the raw sewage (*S. mbandaka* and *S. stanley*), and the final effluent (*S. stanley* and *S. derby*), but the untreated primary sludge had a range of six serotypes. *S. stanley* was found in all types of sewage sample whereas *S. mbandaka*, which formed a dominant part of the raw sewage, was absent from the final effluent and was only one of the six serotypes in the sludge.

Salmonellae were found in 11 (55%) of the 20 samples of gull faeces tested. The 11 isolates comprised seven serotypes (Table 2). *S. stanley* was the dominant type, followed by *S. typhimurium* phage type 40. Three serotypes, *S. stanley*, *S. virchow* and *S. binza*, were common to both gulls and sewage sludge.

DISCUSSION

S. stanley, currently the fourth most frequently isolated serotype from the Scottish human population (CDS Weekly Report, 1982*a*), was the most common isolate from the sewage and gull faeces samples. During the period 1976–80 it occurred rarely (22 human cases) but in 1981 the number of isolations rose sharply (CDS Weekly Report, 1981*b*). Its low original level in humans was reflected in a survey of the gull population in 1979 which failed to isolate the serotype from 1242 faecal samples (Fenlon, 1981). Obviously the increased incidence in humans is now being carried over to the gull population, and it will be interesting to discover if *S. stanley* will now appear in livestock outbreaks for which gulls are implicated as vectors.

S. virchow was the third most common serotype in humans in 1982 and so would be expected in sewage and gulls feeding on it. In 1979 *S. virchow* was the seventh most frequent isolate in both gulls and humans (Fenlon, 1981)

S. binza has rarely been isolated. The only previously reported incident in Scotland in 1982 was among broiler chickens (CDS Weekly Report, 1982*b*). The sewage works does treat some poultry processing waste which may account for the presence of this serotype in the gulls and sewage sludge.

S. typhimurium strangely was not isolated from the sewage samples, although it is the most frequently reported serotype infecting the human population. Phage type 110 is common in human and environmental samples, however phage type 40 occurs less frequently. Earlier in the year it was reported in a reservoir sample in Edinburgh (CDS Weekly Report, 1982*c*), in June it was responsible for a hospital outbreak in Caithness (CDS Weekly Report, 1982*d*) and subsequently it was isolated from sewage and gulls in that area (CDS Weekly Report, 1982*e*).

S. ohio and *S. newport* are isolated frequently from human environmental and animal samples. *S. schwarzengrund* is found infrequently; apart from a few human cases there have been isolates from sheep and a seagull (CDS Weekly Report, 1982*f*).

S. mbandaka is the serotype which does not fit into any pattern. In the raw sewage, allowing for the inaccuracies of the MPN test, it formed about 40% of the salmonella input into the works at the time of sampling. Unlike *S. stanley* it was not found in the final effluent or gulls suggesting an intermittent presence. It was found in the sludge because this accumulates over a 24 h period with periodic mixing and therefore is more representative of the serotypes entering the works on a daily basis, whereas the raw sewage and final effluent isolates represent the input at the time of sampling.

S. mbandaka has only been reported twice in Scotland in the previous 9 months and not for many years in the human population in the Aberdeen area. This suggests either a new serotype to the area which has yet to appear in the official figures, or quite a high level of infection going unreported.

A carriage rate of 55% (11/20 samples positive) confirms earlier work (Fenlon, 1981) showing that the incidence of salmonellae in gulls is related to the proximity of sewage as an available food source. The presence of *S. stanley* in gull faeces and sewage in 1982, compared to its absence from gull faeces and low incidence in humans in 1979 tends to confirm the view that the human population, via sewage,

are responsible for contamination of the gulls. This is supported by finding the rare serotype *S. binza* in both sewage and gulls.

Gulls excreting pathogens are a danger to livestock on pastures (Williams *et al.* 1977) and humans via water supplies (Fennell, James & Morris, 1974). The major options available to prevent faecal contamination of sensitive areas are bird scaring, killing, and denying of access to the sources of pathogens.

Scaring of birds can be achieved by loud noises and recorded distress calls (Slater, 1980). However, the long-term effectiveness has yet to be proved, and the effect is local, leaving the birds to take the problem elsewhere. Widespread use of such measures may cause food shortages among birds which could lead to them overcoming their fear, as happens in harsh winters.

The killing of birds is always an emotive issue especially when dealing with legally protected species. Gulls are widespread, can travel long distances and have an extremely varied diet. In these circumstances localized culling is unlikely to be effective in the long term as birds from surrounding areas will migrate to fill the vacuum (Flegg, 1980). Numbers are only likely to be reduced by a sustained and widespread killing campaign, which is unlikely to be publicly acceptable.

The most efficient method of preventing transmission of pathogens is to remove the source of infection. At sewage works the primary settling tanks are the main attraction to gulls, and could be netted over. The dumping of septic tank waste at tips is often a major source of contamination which could be more effectively controlled. A much more significant problem is the discharge of raw sewage to sea and estuarine waters. Two thirds of Scotland's sewage is discharged untreated (Reilly *et al.* 1981) and throughout Britain during the summer season the sewage from six million people is discharged untreated, 50% to the beach or shallow water. This is not only a health hazard via gulls but directly to the bather (Pearce, 1981), since many of the most polluted areas are the popular resorts.

Gulls are opportunists ready to exploit any available food source such as tips and sewage outfalls (Vernon, 1970, 1972). The herring gull is especially efficient and has been increasing at the rate of 13% a year since 1945 (Coulson & Monaghan, 1978), presumably in response to the available food.

The spread of salmonellae by gulls is only one effect caused by a much wider problem, the indiscriminate disposal of untreated waste by modern society. In 1972 a working party on Environmental Pollution (Report, 1972) suggested, on hygiene grounds, that all sewage discharges to estuarine and coastal waters should be settled or comminuted to remove solids and discharged well below the low tide mark via diffusers to disperse it rapidly. This would remove the particulate material which attracts the gulls and therefore incidentally reduce the carriage of pathogens. Other methods may give localized or transient solutions but would leave the principal problem unaffected.

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REFERENCES

- COMMUNICABLE DISEASES SCOTLAND WEEKLY REPORT (1981 *a*). *Salmonella* infection in wild birds and animals in Scotland, 1978–1980. 81/2, 14, 2, vii–ix.
- COMMUNICABLE DISEASES SCOTLAND WEEKLY REPORT (1981 *b*) 14, 36, v.
- COMMUNICABLE DISEASES SCOTLAND WEEKLY REPORT (1982 *a*) 15, 36, viii.
- COMMUNICABLE DISEASES SCOTLAND WEEKLY REPORT (1982 *b*) 15, 13, xvi.
- COMMUNICABLE DISEASES SCOTLAND WEEKLY REPORT (1982 *c*) 15, 5, xvi.
- COMMUNICABLE DISEASES SCOTLAND WEEKLY REPORT (1982 *d*) 15, 24, v.
- COMMUNICABLE DISEASES SCOTLAND WEEKLY REPORT (1982 *e*) 15, 34, 16–17.
- COMMUNICABLE DISEASES SCOTLAND WEEKLY REPORT (1982 *f*) 15, 12, xii.
- COULSON, J. & MONAGHAN, P. (1978). Herring gulls move into town. *New Scientist* 79, 456–458.
- FENLON, D. R. (1981). Seagulls (*Larus* spp.) as vectors of salmonellae: an investigation into the range of serotypes and numbers of salmonellae in gull faeces. *Journal of Hygiene* 86, 195–202.
- FENNEL, H., JAMES, D. B. & MORRIS, J. (1974). Pollution of a storage reservoir by gulls. *Water Treatment and Examination* 23, 1, 5–20.
- FLEGG, J. J. M. (1980). Biological factors affecting control strategy. In *Bird Problems in Agriculture* (ed. E. N. Wright, I. R. Inglis and C. J. Feare), pp. 7–19. British Crop Protection Council.
- HICKLING, R. A. O. (1967). The inland wintering of gulls in England, 1963. *Bird Study* 14, 104–113.
- JOHNSTON, W. S., MUNRO, D. REILLY, W. J. & SHARP, J. C. M. (1981). An unusual sequel to imported *Salmonella zanzibar*. *Journal of Hygiene* 87, 525–528.
- PEARCE, F. (1981). The unspeakable beaches of Britain. *New Scientist* 91, 139–143.
- RAPPAPORT, F., KONFORTI, N. & VAVON, B. (1965). A new enrichment medium for certain salmonellae. *Journal of Clinical Pathology* 9, 261.
- REILLY, W. J., FORBES, G. I., PATERSON, G. M. & SHARP, J. C. M. (1981). Human and environmental salmonellosis in Scotland associated with environmental contamination, 1973–79. *Veterinary Record* 108, 553–555.
- REPORT (1972). *Environmental Pollution, 3rd Report, Pollution in Some British Estuaries and Coastal Waters*. H.M.S.O.
- SLATER, P. J. B. (1980). Bird behaviour and scaring by sounds. In *Bird Problems in Agriculture* (ed. E. N. Wright, I. R. Inglis and C. J. Feare), pp. 104–114. The British Crop Protection Council.
- STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER (1967). 12 ed. New York: American Public Health Association.
- VERNON, J. D. R. (1970). Feeding habits and food of the black headed and common gulls. 1. Feeding habits. *Bird Study* 17, 287–296.
- VERNON, J. D. R. (1972). Feeding habits and food of the black headed and common gulls. 2. Food. *Bird Study* 19, 173–186.
- WILLIAMS, B. M., RICHARDS, D. W., STEPHENS, D. P. & GRIFFITH, T. (1977). The transmission of *Salmonella livingstone* to cattle by the herring gull (*Larus argentatus*). *Veterinary Record* 100, 45.