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THE TEMPORAL DISTRIBUTION OF INDICATORS (FAECAL COLIFORMS AND FAECAL STREPTOCOCCI) AND OPPORTUNISTIC PATHOGENS (*Candida albicans* and *Pseudomonas aeruginosa*) AT A LAKE ONTARIO BATHING BEACH ON HIGH AND LOW BATHER DENSITY DAYS

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by

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ABSTRACT

In order to examine the temporal relationship between bather load and water quality indicator levels, faecal pollution indicator (faecal coliforms and faecal streptococci) and opportunistic pathogen (*Candida albicans* and *Pseudomonas aeruginosa*) levels were monitored hourly in the nearshore waters of a shallow Lake Ontario bathing beach on a hot August day when the bather load was high, and on two overcast August days when the bather load was negligible. On the high bather load day, an increase occurred in the numbers of faecal coliforms and faecal streptococci in the beach water in conjunction with an increase in the bather load; *P. aeruginosa* levels increased later in the day. There was little apparent relationship between *C. albicans* levels and the other parameters which indicates that, on the high bather load day, *C. albicans* levels could not be predicted by either bacterial indicator levels or bather loads. No corresponding increases were observed for any of the monitored parameters on the low bather load days. The results suggest that bather load and sample collection time may interact to influence estimations of recreational water quality based on faecal pollution indicator and *P. aeruginosa* levels.

RÉSUMÉ

On a étudié l'incidence dans le temps du nombre de baigneurs sur les niveaux des indicateurs de la qualité de l'eau. Pour ce faire, on a relevé, toutes les heures, le niveau de pollution fécale (coliformes et streptocoques fécaux) et le niveau des agents pathogènes opportunistes (Candida albicans et Pseudomonas aeruginosa) près de la rive, dans les eaux peu profondes d'une plage du lac Ontario. Les prélèvements ont tous été effectués en août d'une part, par temps très chaud, lorsque la plage a été envahie par les baigneurs et d'autre part, au cours de deux journées nuageuses au cours desquelles il y a eu peu de baigneurs. Au cours de la journée où il y a eu foule, on a constaté que le taux de coliformes et des streptocoques fécaux dans les eaux de la plage a augmenté parallèlement au nombre de baigneurs tandis que le taux de P. aeruginosa n'a monté qu'en fin de journée. Il ne semblait pas y avoir de lien apparent entre le niveau de C. albicans et les autres paramètres. On conclut donc que lorsque le nombre de baigneurs est élevé, on ne peut prévoir le niveau de C. albicans ni d'après le niveau de pollution bactérienne ni d'après le nombre des baigneurs. Il n'y a eu aucune augmentation correspondante des paramètres à l'étude au cours des journées caractérisées par un nombre de baigneurs restreint. Les résultats obtenus laissent à penser que les évaluations estimatives de la qualité des eaux de plage basées sur les niveaux de pollution fécale et de P. aeruginosa peuvent être influencées par le nombre de baigneurs et les heures de prélèvements des échantillons.

INTRODUCTION

Because of the risk to bathers, a need exists to ensure that recreational waters are not contaminated with disease causing agents. Among the diseases most likely to be contracted by bathers who frequent contaminated waters are (1) eye, ear, nose, and throat infections, (2) skin infections, and (3) gastrointestinal disorders (for a review see Tobin & Dashney, 1978).

Because many of the microorganisms that cause water transmitted diseases are discharged from the intestines of infected persons (Wolf, 1972); and because pathogenic microorganisms are known to occur in the faeces of animals (Geldreich, 1972), the presence of faecal pollution in recreational waters constitutes a potential health hazard.

Bacterial indicators of faecal pollution, such as faecal coliforms and faecal streptococci, are commonly used to monitor the water quality of freshwater recreational beaches.

There are, however, inherent weaknesses associated with this essentially indirect method of detecting the presence of water borne pathogens. For example, coliforms and faecal coliforms can survive and reproduce in chlorinated waste waters (Shuval et al., 1973); low or negligible indicator levels do not preclude the presence of either enteric pathogens (Cherry *et al.*, 1972; Dutka and Bell, 1973), or pathogens shed by bathers who are suffering from eye, ear, upper respiratory tract or skin infections.

Consequently, faecal pollution indicator data would probably be more meaningful if supplemented with data pertaining to the presence of pathogens in recreational water. The availability of improved techniques for the isolation of the opportunistic pathogens *Candida albicans* and *Pseudomonas aeruginosa* (Buck and Bubucis, 1978; Cabelli *et al.*, 1976) facilitates their use as water quality indicators.

C. albicans is a component of the internal flora of mammals and birds, and its occurrence in natural waters has usually been attributed to faecal contamination (Cook, 1970; Ahearn *et al.*, 1968; Combs *et al.*, 1971; Buck & Bubucis, 1978). *C. Albicans* has been proposed as a potential water quality indicator organism (Buck & Bubucis, 1978; Cook and Schlitzer, 1981). Furthermore, as an established agent of mycotic infections in humans, *C. albicans* in beach water may be a health hazard to recreationists.

P. aeruginosa has been associated with eye, ear, upper respiratory tract and skin infections (Young and Armstrong, 1972), and is considered to be the causal agent of swimming related otitis externa (Seyfried & Fraser, 1978).

In a previous survey of the Lake Ontario bathing beaches (Sherry *et al.*, 1979) the highest mean number of faecal coliforms, *P. aeruginosa* and *C. albicans* were observed in either July or August at each beach; highest faecal streptococcal levels were observed in either July or August at 50% of the beaches. Maximum bather loads were observed at the beaches in July with slightly reduced loads in August. The present report concerns the temporal distribution of the foregoing microbial parameters during high and low bather density days at one of the bathing beaches from the original study.

MATERIALS AND METHODS

Sample Collection

Lakeside Park beach (Sherry et al., 1979), the smallest, shallowest, and most enclosed of the beaches originally surveyed, was selected for this follow up investigation. The beach was surveyed on the following dates: August 7, 1978 - an overcast day which turned to rain at 1300 hr. forcing the curtailment of the survey at 1600 hr; August 13, 1978 - a clear and hot day; and August 1, 1979 - an overcast day. Starting at 1000 hours, samples were collected hourly at 1, 10 and 20 m intervals from the shore, on a central transect in the bathing area. At each sampling station, surface water samples (0 to 5 cm in depth) were collected by scooping into a 2 L sterile sampling bottle. The temperature of the water samples was determined immediately after collection. The number of recreationists on the beach and the number of bathers in the water were enumerated while the water samples were being collected.

Microbial Analysis

All microbial analyses were carried out on location in a mobile laboratory.

1. *Candida albicans*:

The *C. albicans* content of water samples was determined in triplicate using the membrane filtration (MF) procedure of Buck and Bubucis (1978). All potentially positive yeast colonies were tested for the ability to produce germ tubes and chlamydospores, which are diagnostic characteristics of *C. albicans* (Sherry *et al*., 1979).

2. Bacterial Parameters:

Faecal coliform, faecal streptococcus and *P. aeruginosa* numbers in the water samples were determined in triplicate using MF procedures described by Dutka (1978).

3. Data:

The microbial data are expressed as the geometric mean of the 1, 10 and 20 m sample values.

RESULTS

1. Recreationist Levels:

On August 7, 1978 and August 1, 1979, which were dull, overcast days, only a small number of recreationists ($\leq$ 30) were present. There was never more than 10 people in the water at sample collection time, on either day. On August 13, 1978, which was a busy day at the beach, the number of recreationists on the beach and the number of bathers in the water increased to peak levels at 1500 hours (Figure 1). The peak recreationst level was 1,000 people on the beach and the peak bather level was 300 people in the water at sample collection time. A steady decline occurred in the number of recreationists and bathers between 1600 and 1900 hours. Bather levels and water temperature were significantly correlated ($P < 0.05$).

2. Water Temperature:

On August 7, 1978, the water temperature increased by about 3°C between 1000 and 1300 hours, at which time a light rain began to fall; by 1400 hours the water temperature had decreased by approximately 2°C; the mean water temperature was 20.5°C. On August 1, 1979 the water temperature increased by approximately 1°C during the sampling period; the mean water temperature was 23.5°C. On the high bather density day (13 August, 1978) the water temperature increased rapidly to approximately 27°C at 1400 hours and remained elevated for the duration of the sample collection period (Table 3); the mean water temperature was 25.8°C; there was little wind.

3. Indicator Levels:

Figure 2a indicates that on August 7, 1978, the first of the low bather density days, the faecal coliform and faecal streptococcus content of the beach water samples declined during the sample collection period; the indictors were not significantly correlated. On August 1, 1979, the second low bather density day, the numbers of faecal coliforms in the water samples (Figure 2b) declined between

1000 hours and 1600 hours; a slight recovery then occurred. The faecal streptococcus levels in the first 4 sample sets fluctuated around 300 CFU/100 mL and then declined to a minimum of about 40 CFU/100 mL at 1900 hours. The faecal streptococcus levels, which were not significantly correlated with the faecal coliform levels, did not recover during the latter portion of the sampling period.

On the high bather density day, an initial decrease in the faecal coliform and faecal streptococcus levels (Figure 3) was followed by a steady increase in the level of both indicators in the water samples. Faecal coliform levels reached a maximum level of about 300 CFU/100 mL at 1600 hours, after which they decreased slightly. Faecal streptococcus levels continued to increase, however, until 1900 hours (Figure 3). The indicators were not significantly ($P > 0.05$) correlated).

4. <u>Opportunistic Pathogen Levels</u>:

Pseudomonas aeruginosa:

On the first low bather density day (Figure 4), the *P. aeruginosa* content of the beach water, which was initially high (> 50 CFU/100 mL), decreased steadily until 1400 hours. Whereas on the second low bather density day (Figure 5b), the *P. aeruginosa* content, which was initially low, fluctuated erratically at low levels.

On the high bather density day, the initially low *P. aeruginosa* levels decreased between 1000 and 1200 hours (Figure 5b) and then belatedly increased between 1500 hours and 1800 hours.

Candida albicans:

C. albicans levels were low in all the samples collected (< 10 CFU/L).

On the first low bather density day, following an initial increase, *C. albicans* levels decreased between 1100 and 1400 hours (Figure 5). On the second low density bather day (Figure 5a) the *C. albicans* levels in the beach water fluctuated for the duration of the sampling period.

On the high bather density day, an initial decrease in *C. albicans*' levels also occurred; an apparent peak occurred between 1400 and 1600 hours (Figure 5a), which coincided with the maximum bather load at the beach. Otherwise, there was little apparent relationship between *C. albicans* levels and the other parameters.

DISCUSSION

On the low bather level days, faecal coliform and faecal streptococcal levels tended to decrease for most of the sample collection period. Levels of the two opportunistic pathogens decreased in a similar manner on the first of the low bather level days. Presuming that a sufficient amount of sunlight penetrated the cloud layer, the foregoing decreases were probably caused by the germicidal effects of sunlight which can affect bacteria to a depth of 3 m in sea water (Fujioka et al., 1981). Seyfried (1980) observed decreased indicator levels on sunny afternoons at freshwater bathing beaches and also concluded that sunlight had probably influenced the surface water counts. The faecal coliform temporal distribution patterns on the low bather level days were similar to the coliform distribution patterns reported by Foster et al. (1971) for two freshwater bathing beaches that had maximum loads of 60-80 bathers at sample collection time.

The increase in faecal coliform levels that occurred toward the end of August 1 sampling period may have several causes. The resuspending action of waves on sediment borne bacteria, a decline in bacterial dieoff rates as a result of decreased afternoon sunlight levels, or a combination of both factors could cause such an effect.

On the high bather level day, after an initial decrease, the levels of both indicators increased steadily for most of the sample collection period. Peak faecal coliform levels coincided with peak bather levels. The apparent relationship between the levels of water borne bacteria and bather levels may have several causes: shedding of bacteria by bathers, suspension of sediment bacteria by bather action, transportation by bathers of bacteria from the sand to the water, or a combination of these factors.

The shallower water and higher bather levels at Lakeside Park beach were probably conducive to a more immediate and pronounced bather impact on water column indicator levels than was observed at the two beaches examined by Foster et al. (1971).

Excessive bather loads, particularly at shallow beaches, may contribute to the microbial degradation of recreational water quality. Also, it appears that bather levels and sample collection time may interact, within the constraints of a beach's physical dimensions, to influence indicator levels in the water column. Afternoon indicator levels can be an order of magnitude higher or lower than morning levels depending on whether bather levels are high or low respectively. In both cases, the choice of sample collection time may influence estimations of the degree of water quality degradation. On high bather load days, water samples for use in the determination of faecal pollution indicator levels should be collected in mid-afternoon in order to realistically determine the potential hazard to bather. On low bather load days, water samples should be collected in the morning in order to accurately determine the extent of water quality degradation. The desirability of monitoring faecal pollution indicator and pathogen levels in the sediment of lightly used, calm beaches warrants further consideration, as does the relationship between the levels of indicators and pathogens in the sediment and water of freshwater bathing beaches.

Further research should establish whether similar relationships occur at other freshwater bathing beaches. Additional data pertaining to the occurrence of *C. albicans* at freshwater bathing beaches should be acquired as a prelude to an examination of the public health significance of *C. albicans* in bathing beaches.

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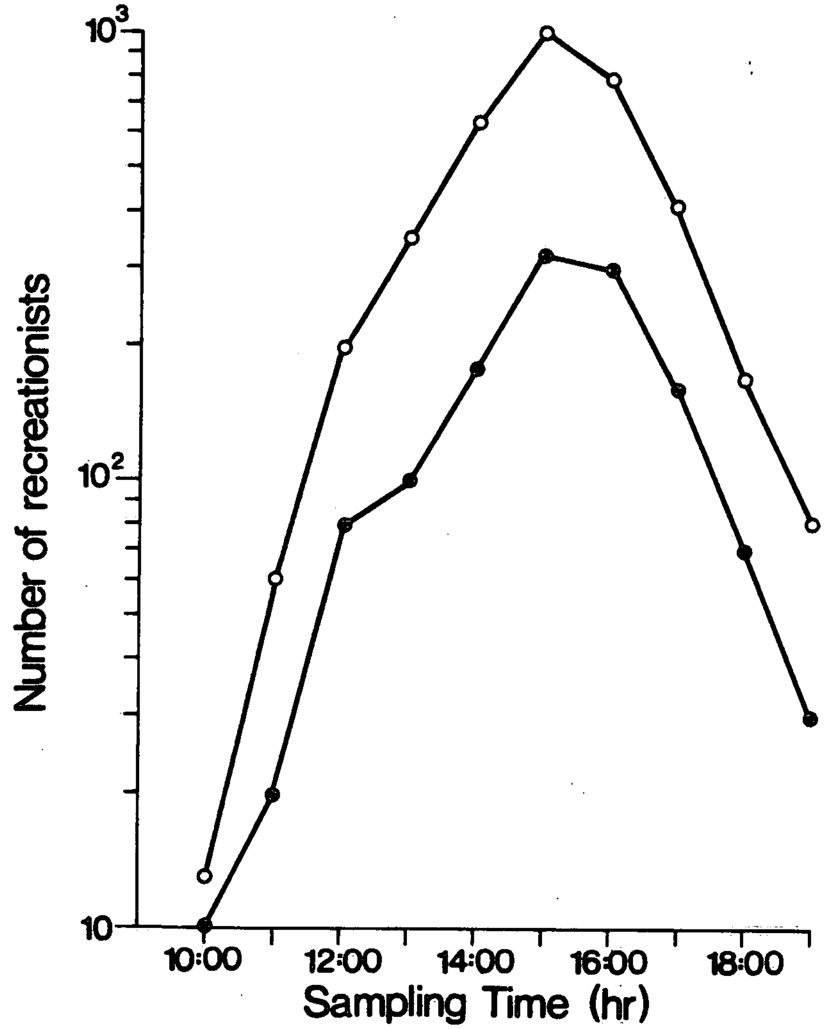
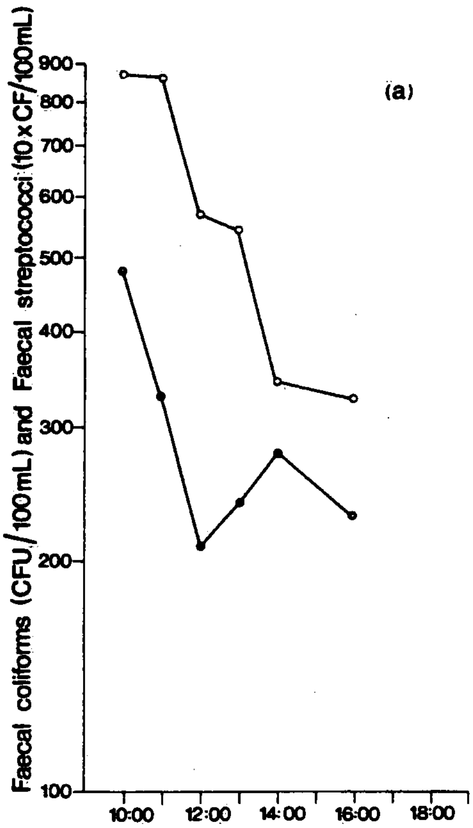
Figure 1. Number of recreationists at Lakeside Park Beach, 13 August 1978. o, total number of recreationists on beach; ●, number of bathers in water.



10³
10²
10
Number of recreationists
10:00
12:00
14:00
16:00
18:00
Sampling Time (hr)

Figure 2. Temporal distribution of bacterial faecal pollution indicator organisms on low bather level day at Lakeside Park Beach, (a) August 7, 1978; (b) August 1, 1979.
o, faecal coliforms, ● , faecal streptococci.


Faecal coliforms (CFU/100mL) and Faecal streptococci (10 x CF/100mL)
900
800
700
600
500
400
300
200
100
(a)
10:00
12:00
14:00
16:00
18:00

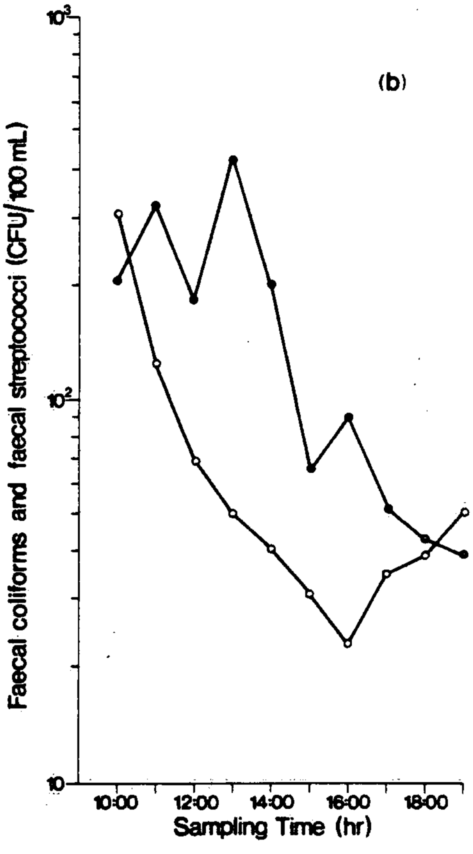
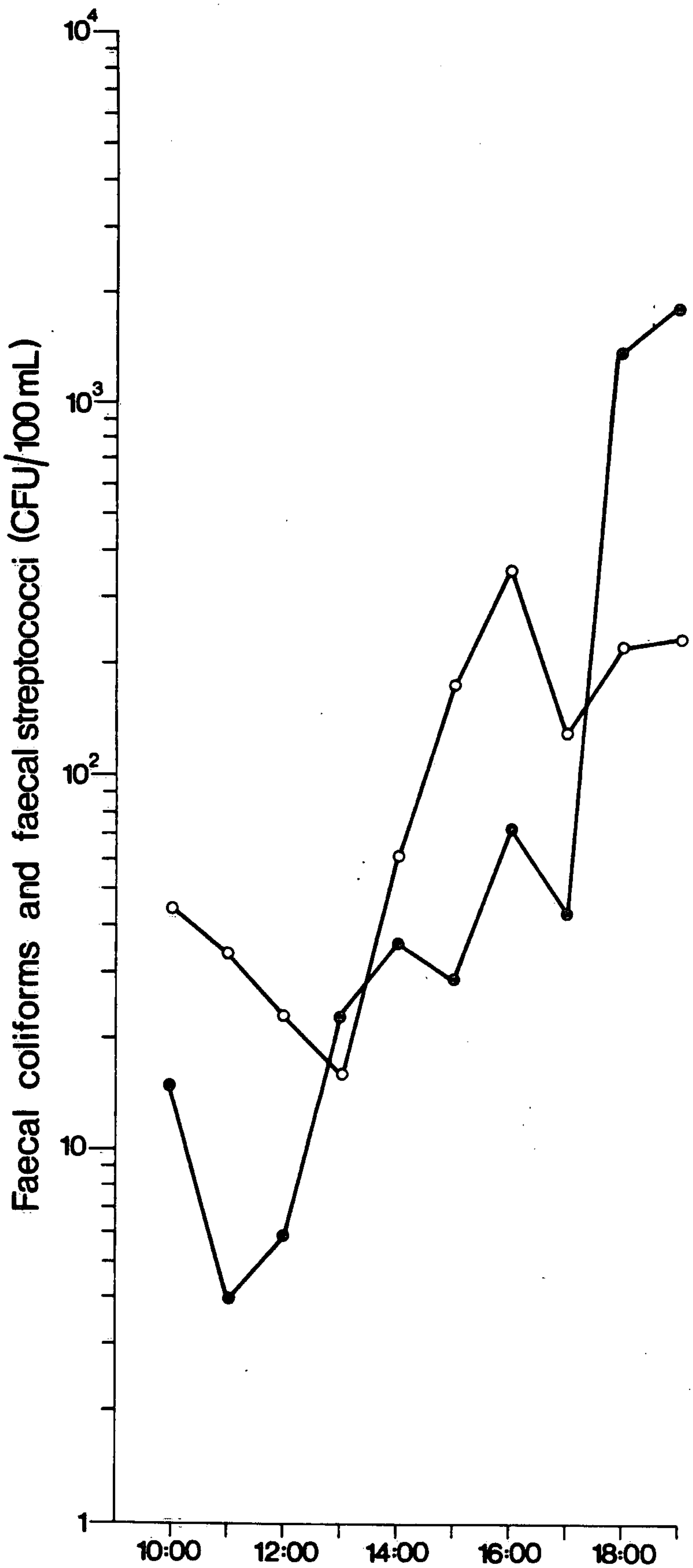
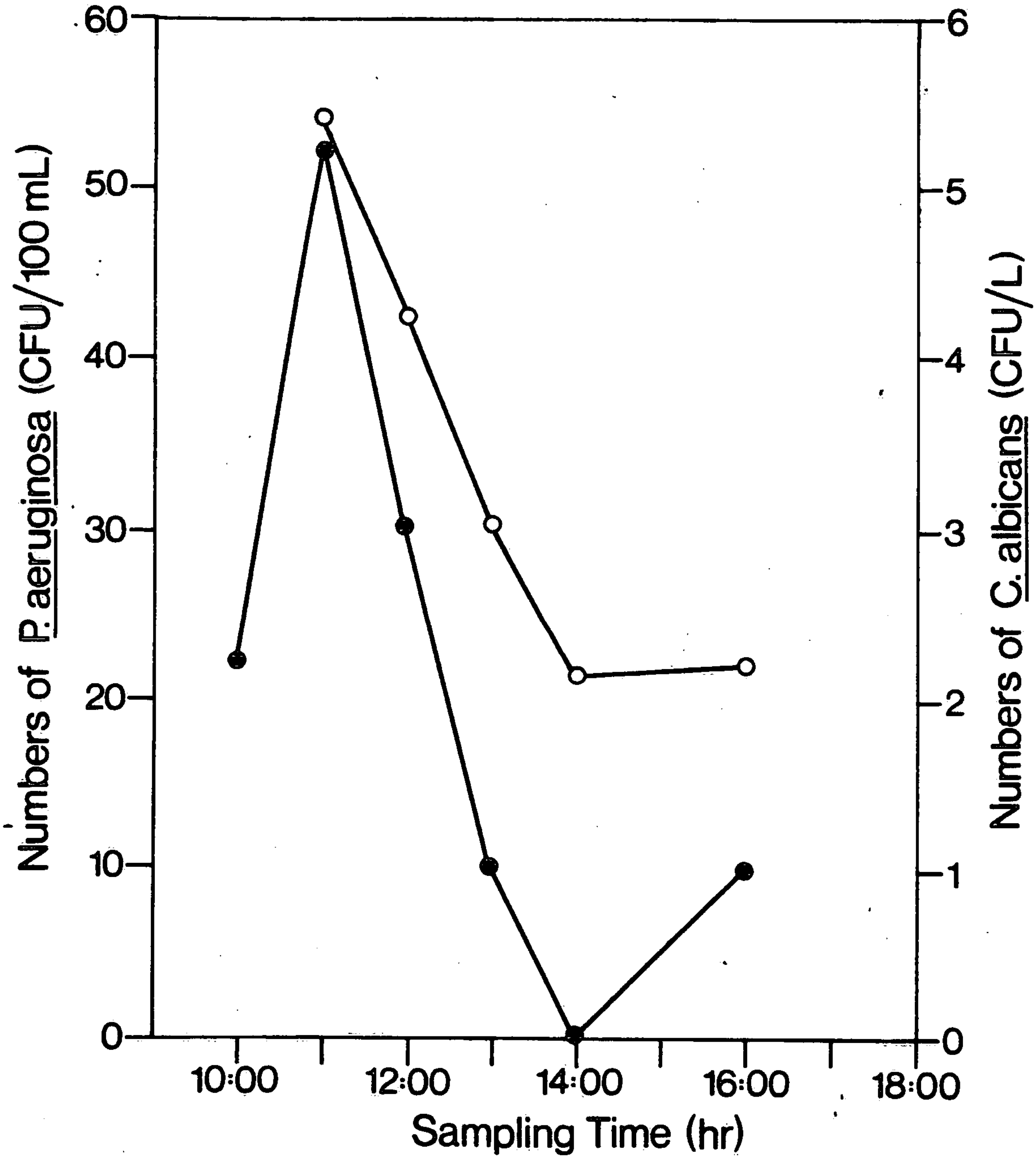

Faecal coliforms and faecal streptococci (CFU/100 mL)
10^3
10^2
10
(b)
10:00
12:00
14:00
16:00
18:00
Sampling Time (hr)

Figure 3. Temporal distribution of bacterial faecal pollution indicator organisms on August 7, 1978 a high bather level day at Lakeside Park Beach.
o, faecal coliforms, ● , faecal streptococci.



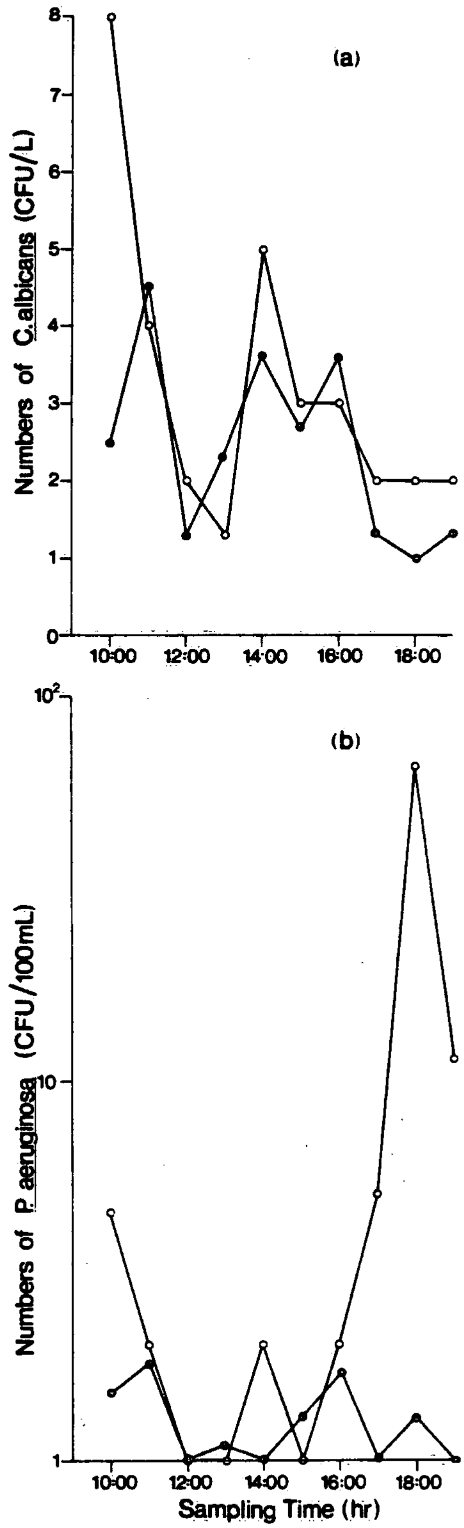
Faecal coliforms and faecal streptococci (CFU/100 mL)
10^4
10^3
10^2
10
1
10:00
12:00
14:00
16:00
18:00
Sampling Time (hr)

Figure 4. Temporal distribution of *P. aeruginosa* (o) and *C. albicans* (●) at Lakeside Park Beach on August 7, 1978, a low bather level day.



Numbers of P. aeruginosa (CFU/100 mL)
60
50
40
30
20
10
0
Numbers of C. albicans (CFU/L)
6
5
4
3
2
1
0
10:00
12:00
14:00
16:00
18:00
Sampling Time (hr)

Figure 5. Temporal distribution of *P. aeruginosa* (a) and *C. albicans* (b) at Lakeside Park Beach on high (August 13, 1978) (o) and low (August 1, 1979) (●) bather level days.


(a)
Numbers of C.albicans (CFU/L)
8
7
6
5
4
3
2
1
0
10:00
12:00
14:00
16:00
18:00
(b)
Numbers of P. aeruginosa (CFU/100mL)
10^2
10
1
10:00
12:00
14:00
16:00
18:00
Sampling Time (hr)