

Preliminary observations on the benthic macrofauna of a polluted coastal lagoon in Ghana (West Africa)

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Abstract: Four species of gastropods (*Lymnaea truncatula*, *Melanooides tuberculata*, *Turritella annulata*, and *Biomphalaria* sp.) and three of insect larvae (*Chironomus* sp., *Peltodytes* sp. and *Pseudagrion* sp.), were sampled during a preliminary survey of the macrozoobenthos of a polluted Ghanaian lagoon (Fosu Lagoon: 1°16'W, 5°07'N) in January 1993. *L. truncatula* constituted about 91% of the biomass of the community, suggesting that it might be an 'opportunist' under the prevailing conditions in the lagoon. The estimated Shannon-Weiner index ($H=0.34$), and equitability index ($J=0.17$), respectively, indicated a low species diversity and uneven distribution of individual numbers among the species compared with estimates for the macrozoobenthos in non-polluted or less polluted waters. Anoxic and low dissolved oxygen conditions attributable to organic pollution, and unfavourable salinities, may be the principal factors accounting for the current state of diversity, distribution and abundance of the benthic macrofauna of the lagoon.

Résumé: Quatre espèces de gastéropodes (*Lymnaea truncatula*, *Melanooides tuberculata*, *Turritella annulata* et *Biomphalaria* sp.) et trois espèces d'insectes (*Chironomus* sp., *Peltodytes* sp. et *Pseudagrion* sp.) ont été échantillonnées lors d'un inventaire préliminaire de la macrofaune benthique d'un lagon ghanéen pollué (le lagon de Fosu; 1°16'O, 5°07'N) en janvier 1993. *L. truncatula* constitue environ 91% de la biomasse du peuplement, ce qui suggère qu'elle a un comportement opportuniste dans les conditions actuelles du lagon. L'indice de diversité de Shannon-Wiener ($H=0,34$) et l'indice d'équitabilité ($J=0,17$) estimés indiquent une diversité spécifique plus faible et une distribution des individus entre espèces moins équilibrée que dans les eaux non ou peu polluées. Les conditions anoxiques et le faible taux de dissolution de l'oxygène dus à la pollution organique, ainsi que la salinité peu favorable, sont sans doute les principaux facteurs qui expliquent la diversité, la distribution et l'abondance actuelles des espèces de la macrofaune benthique du lagon.

Resumen: Se muestrearon cuatro especies de gasterópodos (*Lymnaea truncatula*, *Melanooides tuberculata*, *Turritella annulata*, y *Biomphalaria* sp.) y tres larvas de insectos (*Chironomus* sp., *Peltodytes* sp. y *Pseudagrion* sp.) durante un muestreo preliminar, en enero de 1993, del macrozoobentos de una laguna contaminada en Ghana (Laguna Fosu; 1°16'W, 5°07'N). *L. truncatula* constituyó cerca del 91% de la biomasa de la comunidad, sugiriendo que pudiera ser un oportunista bajo las condiciones prevaescentes en el lago. El índice estimado de Shannon-Wiener ($H=0.34$), y el índice de equitabilidad ($J=0.17$), indican una baja diversidad de especies y una distribución no homogénea del número de individuos entre las especies, comparada con los estimados para el macrozoobentos en aguas no contaminadas o menos contaminadas. Los principales factores que explican el estado actual de la diversidad, distribución y abundancia de la macrofauna bentónica de la laguna, son la anoxia y las condiciones de bajo oxígeno disuelto atribuibles a la contaminación orgánica, así como las salinidades desfavorables.

Resumo: Durante um inventário preliminar dos macrozoobentos numa laguna poluída no Ghana (Laguna de Fosu; 1°16'O, 5°07'N) em Janeiro de 1993, foram amostradas quatro espécies de gastropodos (*Lymnaea truncatula*, *Melanooides tuberculata*, *Turritella annulata* e *Biomphalaria* sp.) e três larvas de insectos (*Chironomus* sp., *Peltodytes* sp. e *Pseudagrion* sp.). O *L. truncatula* constituía cerca de 91% da biomassa da comunidade, sugerindo

que seja, nas actuais condições da laguna, uma espécie oportunista. Os índices estimados de Shannon-Weiner ($H=0.34$) e de equitabilidade ($J=0.17$) indicam uma diversidade específica baixa e uma distribuição desigual do número de indivíduos entre as espécies comparadas com as estimações feitas para os macrozoobentos em águas não poluídas ou menos poluídas. A anóxia e as condições de baixo oxigénio dissolvido, atribuível à poluição orgânica e a salinidades desfavoráveis, podem ser os principais factores responsáveis pela situação actual quanto à diversidade, distribuição e abundância da macrofauna bêntica da laguna.

Key Words : 'Closed' lagoon, distribution and abundance, diversity, macrozoobenthos.

Introduction

Benthic fauna are among the least investigated of the biotic communities in West African lagoons, despite their importance in the transfer of matter and energy in aquatic ecosystems. Past investigators of the lagoons placed considerable emphasis on their physico-chemical characteristics and plankton productivity (Biney 1986, 1990; Boughey 1957; Kwei 1977), fish biology (Blay 1995; Fagade & Olaniyan 1972), and fisheries (Blay & Asabere-Ameyaw 1993; Pauly 1976; Welcomme 1972). There are some 98 coastal lagoons in Ghana (K. Yankson, personal communication) many of which provide economic and nutritional benefits to the communities residing near them (Mensah 1979). To date, only the 'semi-closed' Sakumo lagoon has been studied for its benthic faunal composition, abundance and distribution (Pauly 1975), but the extent of diversity of the community was not assessed. Although recent work on 16 Ghanaian lagoons (Biney 1982) has shown that 12 are organically polluted to various degrees, some remain valuable fisheries resources (e.g. Blay & Asabere-Ameyaw 1993; Pauly 1976). Knowledge of the ecology of these lagoons would doubtless enhance our perception of the relationship between fish production and the production rates of their food sources, of which the benthos is an important component. The present investigation assesses the diversity, distribution and abundance of the macrozoobenthos in a 'closed' lagoon receiving polluting discharges.

Study area

The study was conducted in the Fosu Lagoon located in Cape Coast, approximately 150 km west of Accra, Ghana (Fig. 1). At maximum level, it has a surface area of 0.61 km² and a mean depth of 1.5 m. The lagoon is 'closed' to

the sea by a sand bar which occasionally is breached by rain floods or sand winning activities. The lagoon, therefore, has a relatively poor water exchange, being fed principally by rain water and domestic effluents, and occasional spills of sea water. It receives large quantities of organic sewage from the Cape Coast municipality, the mean particulate organic matter (POM) content of which was approximately 1400 mg l⁻¹, generating a biochemical oxygen demand (BOD) in the range 27.2 mg l⁻¹ to 94.6 mg l⁻¹. Other pollutants include solid wastes such as scrap metal, plastic products, fabric, footwear, and sawdust.

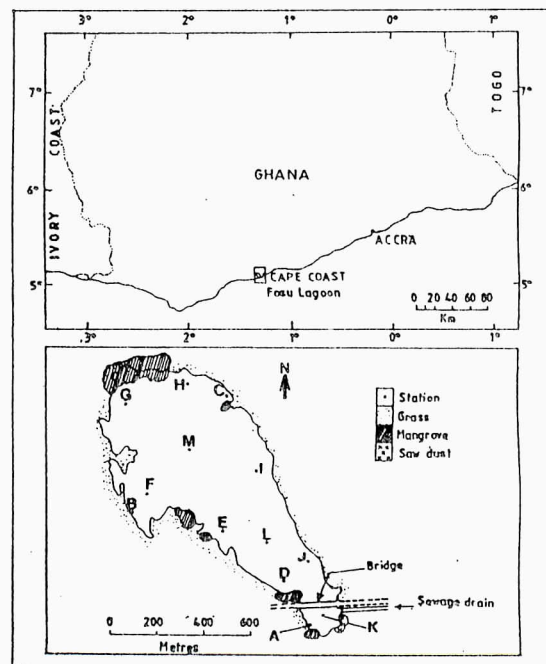


Fig. 1. Map showing the location of Fosu Lagoon and the sampling stations.

Blooms of the blue-green algae, *Anabaena* sp., *Spirulina* sp. and *Oscillatoria* sp., and the protozoan flagellates, *Euglena* sp., characteristic of organically polluted waters (Cole 1979; Hynes 1960) are common. The grass, *Paspalum vaginatum*, is the main fringing vegetation, while patches of the white mangrove, *Avicennia africana*, occur in a few areas (Fig. 1).

The substratum is predominantly soft, dark grey mud, but near the shores it consists of a mixture of mud and decaying vegetable matter.

Materials and methods

The benthos was sampled from 13 randomly selected stations (Fig. 1) on 16 and 20 January 1993, using a 225 cm² (15 cm x 15 cm) Ekman grab. Three stations (A, B and C) occurred close to the shore where the water was 0.15-0.25 m deep, seven stations (D, E, F, G, H, I and J) were located in water 0.35-0.71 m deep, and three other stations (K, L and M) were situated where water depth was 0.77-1.30 m. Two samples were taken at every station and, in the laboratory, washed through a 600 µm net. Animals retained in the mesh were sorted, identified, counted and weighed by species after blotting off excess fluid. Results of the density and biomass of the different populations are reported as means of two samples (cf. Okedi 1990; Tudorancea & Harrison 1988). Empty mollusc shells were excluded from the analysis.

The diversity of the benthic fauna was assessed by the Shannon-Weiner index (H), calculated as:

$$H = - \sum_{i=1}^s P_i (\ln P_i)$$

where P_i is the proportion of individuals belonging to species i , and s is the number of species in the community (Begon *et al.* 1990); the equitability, or evenness (J) was calculated as the ratio H/H_{\max} , where H is the observed species diversity, and $H_{\max} = \ln s$.

Samples of water were taken from the surface (except at shallow stations A, B and C), and the concentration of oxygen was determined by the Winkler method (Wetzel & Likens 1979). Salinity of the samples was measured with a portable Fisher salinity and conductivity meter (model 152), and surface and bottom temperatures were recorded with a thermometer installed in the water sampler.

Results

Temperature, dissolved oxygen and salinity

There was little difference in the temperature among the various stations and, as the lagoon is generally shallow, differences in the surface and bottom temperatures were minimal, not exceeding 1.5°C at any given station (Table 1). At most stations, the concentration of dissolved oxygen was lower in the bottom waters, probably due to the decomposition of deposits of organic matter. At station K, decomposition of accumulated sewage and sawdust may have contributed to the hypoxic condition (< 2 mg l⁻¹) at the surface, and deoxygenation at the bottom. The salinity of the lagoon was considerably lower than that of the sea (36‰) because of dilution by rain water and domestic effluents.

Distribution, density and biomass of macrofauna

In all, seven species of macrobenthic animals comprising four species of gastropods and three species of insect larvae were sampled, and their distribution, density and biomass are illustrated in Fig. 2. Empty shells of two other snails, *Aplexa waterlotii* (Physidae) and *Hydrobia accrensis* (Hydrobiidae), and those of unidentified bivalves, were also present in the samples. *Lymnaea truncatula* (Lymnaeidae) was collected from shallow to deeper zones except stations K and L, although shells of this snail were present at station L. The highest density of 288,911 individuals m⁻² was recorded at station B with a corresponding standing biomass of 523 g m⁻². *Melanoides tuberculata* (Melaniidae) was found in shallow and slightly deeper water. Empty shells were encountered at station M where the water was 0.77 m deep. This snail was most abundant at station B with a density of 2,178 m⁻², and a biomass of 76 g m⁻². Two other gastropods, *Turritella annulata* (Turritellidae) and *Biomphalaria* sp. (Planorbidae) were sampled at stations A and B, respectively. *T. annulata* had a density of 44 m⁻², and a biomass of 0.30 g m⁻², while *Biomphalaria* sp. had a density of 44 m⁻² and a biomass of 0.02 g m⁻².

With regard to the insect larvae, *Chironomus* sp. (Chironomidae) were sampled from stations farther from the shore (stations D, E, F, G, H, J and M). The highest density of 1,178 m⁻² and biomass of 4.5 g m⁻² were recorded at station D. Larvae of *Peltodytes* sp. (Halipidae) occurred in the shallow stations (A and C) where respective densities of 22 m⁻² and 44 m⁻², and corresponding biomasses of 0.07 g m⁻² and 0.20 g m⁻² were recorded.

Table 1. Some hydrological conditions at 13 stations in the Fosu Lagoon on 20th January 1993 with the depth of water (m) at each station given in parenthesis; the value for each station is the mean of two measurements.

Hydrological factor		Sampling Stations												
		A (0.20)	B (0.25)	C (0.15)	D (0.40)	E (0.35)	F (0.40)	G (0.35)	H (0.71)	I (0.66)	J (0.57)	K (1.30)	L (1.10)	M (0.77)
Temperature (°C)	Surface	24.5	25.5	25.5	24.0	24.0	24.0	24.5	24.7	25.0	25.5	24.0	25.5	24.5
	Bottom	24.5	25.0	25.5	23.8	24.0	23.8	24.5	24.0	24.5	25.0	23.0	24.0	24.0
Dissolved Oxygen (mg l ⁻¹)	Surface	-	-	-	10.8	8.5	14.4	9.4	5.7	6.7	8.1	1.3	7.6	8.2
	Bottom	2.6	4.2	4.9	4.1	7.9	10.8	6.7	3.3	3.3	4.0	0.0	5.4	6.9
Salinity (‰)		13.0	15.5	14.0	13.0	14.0	14.0	15.0	14.5	13.0	12.0	12.0	13.5	14.0

Nymphs of the damselfly, *Pseudagrion* sp. (Coenagridae), were similarly restricted to shallow areas (stations A and C) near the fringing vegetation. The density at each station was 22 m⁻², and the biomass, 0.03 g m⁻².

1984) and the coastal waters off Barcelona in the western Mediterranean ($H=2.77$). As the equitability component of the diversity is far less than unity (Begon *et al.* 1990), it is inferred that there was an uneven distribution of individuals among the different species.

Species diversity

L. truncatula clearly dominated the macrozoobenthos of the lagoon, constituting about 91% of the biomass of the community (Table 2). In view of the apparent low species richness of the community at each of the 13 stations, the data for all stations were combined for assessment of the diversity, density and biomass of the macrozoobenthos in the lagoon. The Shannon-Weiner index of diversity (H) was calculated to be 0.34, and the species equitability (J), as 0.14. The present estimate of the diversity index for the Fosu Lagoon is low compared to average estimates for the Gulf of Nicoya in Costa Rica ($H=0.91$) (Maurer & Vargas

Table 2. Percent composition (by weight) of the different species in the macrozoobenthos of the Fosu Lagoon.

Species	Mean standing crop ¹ (g m ⁻²)	Composition (%)
Gastropods		
<i>Lymnaea truncatula</i>	73.30	90.56
<i>Melanoides tuberculata</i>	7.20	8.89
<i>Turritella annulata</i>	0.02	0.03
<i>Biomphalaria</i> sp.	0.02	0.003
Insect larvae		
<i>Chironomus</i> sp.	0.40	0.49
<i>Peltodytes</i> sp.	0.02	0.03
<i>Pseudagrion</i> sp.	0.01	0.01

¹Based on 2 samples at each of 13 sampling stations.

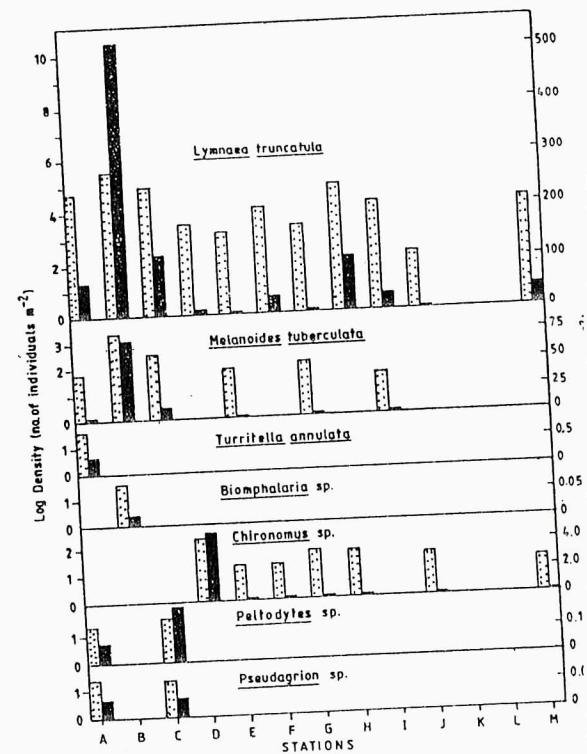


Fig. 2. Density (□) and biomass (■) of the benthic macrofauna at the different stations in the Fosu Lagoon. Each bar represents the mean of two values.

Discussion

The dearth of information on the macrozoobenthos of 'closed' and other types of lagoons limits comparison of the present study in the Fosu Lagoon (Ghana) with other works. For this reason, and the fact that the investigation was limited to a brief period of the year, it is imperative to interpret these results with caution. Nevertheless, this report could form a useful reference base for future work on macrobenthic communities in similar habitats in other West African countries.

Compared with the macrozoobenthos in a Costa Rican estuary for which a mean diversity index (H) of 0.91, and equitability (J) of 0.76 were estimated (Maurer & Vargas 1984), the present results obtained for the Fosu Lagoon might suggest a low species diversity and low 'evenness'. About 22 macrobenthic species were sampled by Pauly (1975) in the 'semi-closed' Sakumo Lagoon (Ghana), which indicates a greater species richness than the Fosu Lagoon community. Unfortunately, estimates of the diversity and equitability with which our results could be compared were not given.

Several factors influence the diversity, spatial distribution and abundance of benthic organisms (Tudorancea *et al.* 1989) and, in aquatic habitats, stressful conditions are known to result from low dissolved oxygen regimes, high hydrogen sulphide levels, fluctuating salinity, high temperatures, high turbidity and predation effects (Llansó 1992; Tudorancea & Harrison 1988). Of these, low dissolved oxygen and high salinities engendered by sudden influxes of sea water may have accounted for the low diversity and low equitability of the macrozoobenthos in the Fosu Lagoon.

In a comparative study of the state of pollution in Ghanaian coastal waters, the Fosu Lagoon was categorised as 'moderately polluted' (Biney 1982) based on an estimated biological oxygen demand (BOD) of 25 mg l^{-1} , and a consideration of its polluting effluents. Organic sewage constitutes the main pollutant of the lagoon (annual BOD range, $27.2\text{--}94.6 \text{ mg l}^{-1}$), and might be responsible for the deoxygenation and low oxygen levels determined in some parts of the lagoon (Table 1). The persistent putrid smell of the water, attributable to the emission of hydrogen sulphide from the sediments, provides further evidence of a high rate of organic decomposition in the lagoon, and fish kills have occasionally been observed following strong emissions of this gas (Blay, personal obs.). Under such conditions, the development of the benthic and other

communities could be hampered. Work in the Tees estuary, U.K. (Tapp *et al.* 1993) revealed that excessive increase in organic enrichment led to a decline in the diversity and abundance of the benthic fauna. In the Fosu Lagoon, lack of benthic animals at Station K, a major effluent discharge zone and dumping site for sawdust from a nearby mill (Fig. 1) coincided with the prevailing anoxic situation possibly generated by an increased biological oxygen demand (BOD). A similar defaunation due to deoxygenation has been reported in some coastal waters (Ros & Cardell 1991; Swanson & Sindermann 1979, quoted in Llansó 1992). However, the absence of live animals from Station L despite the prevailing favourable oxygen level might suggest the occurrence of periodic unfavourable conditions leading to mass mortalities or emigration of the animals. Although Station A is closer to K than any other station, and has a rather low bottom dissolved oxygen content, it has a moderate amount of life possibly because it is shallow, and productivity here was high in addition to other conditions remaining fairly stable for the sustenance of some species.

The salinity of the Fosu Lagoon remains lower than that of the sea throughout the year; Blay & Asabere-Ameyaw 1993 reported an annual range of 1.6–6.2‰. Of the benthic animals sampled from the lagoon, the gastropod, *Turritella annulata*, taken at Station A, is the only species adapted to saline waters; *Lymnaea truncatula*, *Melanoides tuberculata* and *Biomphalaria* sp., and the insect larvae, *Chironomus* sp., *Pelodytes* sp. and *Pseudagrion* sp., are typically freshwater species. Conceivably, a sudden rise in salinity beyond tolerable limits, as may occur with large influxes of sea water during high tide, or excessive evaporation, could be detrimental to the survival and development of a majority of the fauna. Tudorancea & Harrison (1988) stated that saline waters are unsuitable for habitation by many aquatic organisms due to their high osmotic pressures, high pH and unfavourable ionic properties.

As observed for the diversity, the spatial distribution of the macrobenthic fauna may similarly have been determined by the conditions prevailing at different parts of the lagoon. Judging from its wider distribution and greater abundance in the community, *L. truncatula* may have been better adapted to the 'harsh' environmental conditions in the lagoon than the other species, in which event it could be classified as an 'opportunist', as noted for some species in stressed waters (Dauer *et al.* 1992; Llansó 1992; Ros & Cardell 1991). This may part-

ly be attributed to the abundance of its detrital food, and the ability to utilise atmospheric oxygen when its dissolved oxygen requirement falls below the critical level (Meglitsch 1972; Prosser 1973).

Chironomid larvae are reportedly tolerant of low oxygen levels in the sediments of lake ecosystems (Moss 1980; Tudorancea *et al.* 1989). This habit might similarly explain the presence of *Chironomus* larvae in the relatively deeper offshore stations in the Fosu Lagoon subject to deoxygenation, and where nevertheless their finely divided detrital food abounds. The occurrence of the carnivorous larvae, *Pelodytes* sp. and *Pseudagrion* sp. in the littoral zones could also be due to the high productivity in these areas ensuring a ready supply of prey, and the shallowness of the water permitting easy access to the well-oxygenated surface.

Considering the minor differences occurring in the salinity at the different stations (Table 1), this factor was unlikely to have significantly influenced the distribution of the benthic fauna. Differences in the extent of organic input resulting in different oxygen levels at the various locations, and food availability were more likely to have accounted for the distribution of the benthic fauna in the lagoon.

The macrozoobenthos constitutes an important link in the trophic relationships among the various communities in aquatic ecosystems. Its estimated low abundance and diversity in the Fosu Lagoon could therefore be implicated in the low species richness of the ichthyofauna dominated by the plankton-eating tilapia, *Sarotherodon melanotheron* (Rüppel) (see Blay & Asabere-Ameyaw 1993). Of the fishes in the lagoon, the goby, *Porogobius schlegelii* Günther, is the only feeder of macrobenthic fauna (Blay, unpublished obs.). Presumably, the absence of other macrobenthophagous fish is a consequence of the detrimental effects of pollution on their potential food sources.

A coincidence of improved water quality with benthic biology following a decline in organic input has been reported in the Tees estuary (U.K.) (Tapp *et al.* 1993). It may therefore be expected that a similar improvement in the status of the Fosu Lagoon benthos would be manifest during the rainy season (May-September) when dilution of the pollutants is likely to bring about a healthier environment, compared to the dry season (October-April). Further studies dealing with seasonal variations in the diversity, abundance and distribution of the macrobenthic fauna might throw more light on the response of these attributes to changes in the environmental conditions in the lagoon.

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