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Mercury in the Bivalves *Crassostrea tulipa* and *Perna perna* from Ghana

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The coastline of Ghana consists mainly of plains with numerous lagoons and estuaries; about 50 lagoons occur in the area, most of them very small (less than 1 km^2). They are of two main types: 'open' and 'closed' lagoon systems. The open lagoons are in contact with the sea throughout the year and are therefore under tidal influence. The salinity is similar to that of the sea except during the wet season, when it is lowered as a result of dilution from surface run-off and streams; water temperature ranges from 24°C to 32°C, salinity from 10 to 40 PSU. The closed lagoons are cut-off from the adjacent sea by a sand bar (about 40 m wide) for the greater part of the year, while contact with the sea is re-established during the wet season; water temperature ranges from 27°C to 34°C, salinity from 27 to 70 PSU. Dilution is mainly from direct rainfall and small creeks, whereas hypersaline conditions result from evaporation during the dry season (Biney, 1986; Yankson, 1982). There are two wet seasons per year, the major one from March to July and a minor one from September to October, separated by a short cold dry season in August and a relatively long warm dry season from mid-October to March. The annual rainfall averages 2 m, but varies greatly.

Most animals can regulate their tissue concentrations of essential heavy metals up to a certain concentration, above which accumulation starts and toxic effects may occur. However, non-essential metals such as mercury (Hg) and cadmium (Cd) are considered not to play any biological role, and are therefore potentially toxic even at low concentrations (e.g., Amiard *et al*., 1987). Bivalves are often proposed as good bioindicators, reflecting the levels of ambient environmental pollution (e.g., Boyden and Phillips, 1981).

The aim of this study is to investigate whether the trends in Hg concentration previously reported for the cockle *Anadara (Senilia) senilis* from West Africa (Joiris *et al*., 1998) are similar for oysters and mussels, since different bivalves may exhibit distinct capacities for contaminant excretion, accumulation and metabolism (Tanabe *et al*., 1987; Reinfelder *et al*., 1997).

Oysters, *Crassostrea tulipa* (= *C. gasar*), were collected from three lagoons in Ghana ($n = 356$): Benya and Ningo (open lagoons), and Sakumo (a closed lagoon) during the 1996 wet season and the 1997 dry season. Mussels, *Perna perna*, were collected from rocky shores adjacent to Benya and Sakumo lagoons during the same periods ($n = 208$).

The methods used to determine total mercury ($\sum$Hg) by specific atomic absorption, and organic mercury (MeHg) by liquid-gas chromatography with electron-capture detection, as well as quality control and detection limits, have been described in detail by Joiris *et al.* (1995, 1998). The condition index used here was the ratio between soft tissue weight (mg dry weight) and shell length (cm). Differences were tested using the Mann–Whitney-U test of significance; median values are reported instead of means, because of the non-normal distribution of the data.

Total mercury concentrations in the oyster did not show any clear effect of length, i.e. of age (Fig. 1). A

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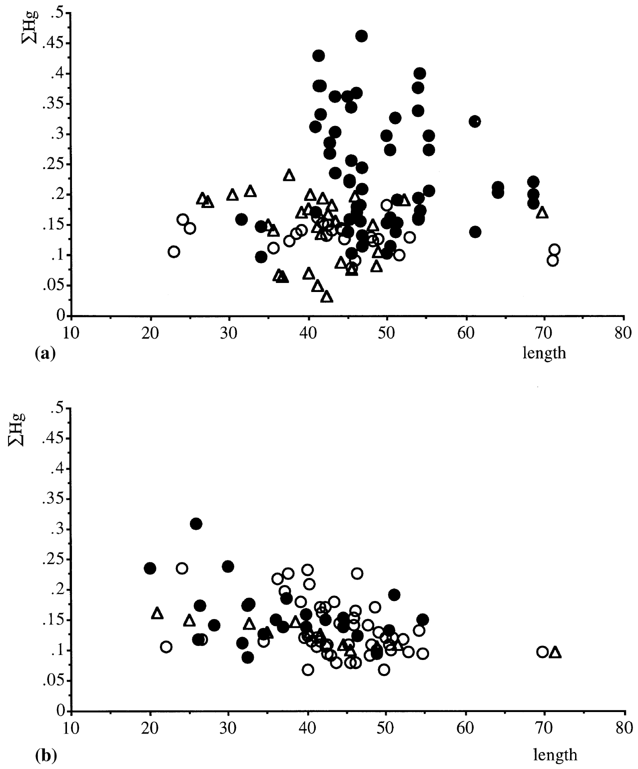

Fig. 1 Total Hg concentration (μg g^{-1} dry weight) in oysters from Ghana as a function of total shell length (mm). Filled circles: Benya; open circles: Sakumo; triangles: Ningo. (a) dry season, (b) wet season.

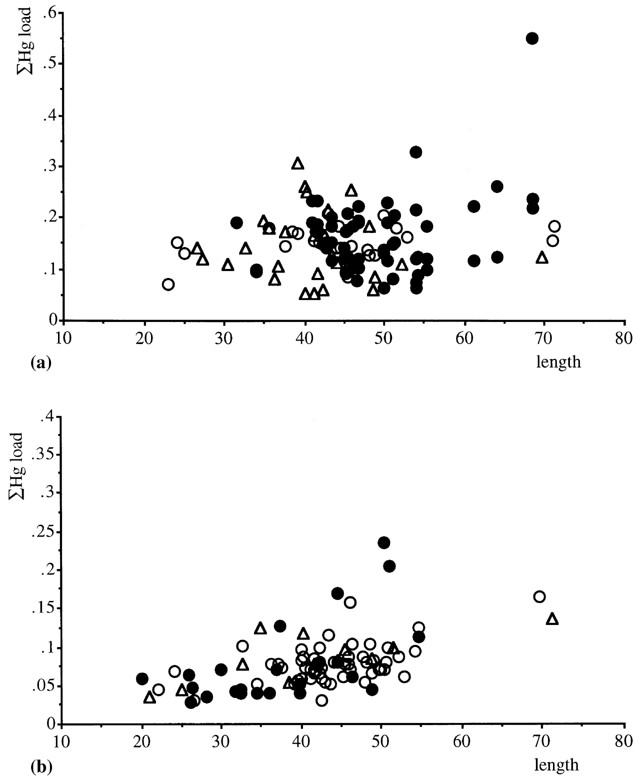

Fig. 2 Total Hg load (μg) in oysters from Ghana as a function of total shell length; see legend in Fig. 1.

mean Hg concentration of 0.06 μg g^{-1} wet weight was found in oysters and in cockles from this area (Biney *et al.*, 1994), equivalent to 0.4 μg g^{-1} dry weight, similar to the concentrations reported here (Table 1). Concentrations were also similar to those detected in the cockle *Anadara (Senilia) senilis* from Ghana and Nigeria (Joiris *et al.*, 1998). Spatial variations seem to reflect the degree of urbanization (Benya > Ningo > Sakumo), and are similar to the variations of Hg concentration reported in commercial fish along the

TABLE 1

Total mercury and methylmercury concentrations (μg g^{-1} dry weight) in the oyster *Crassostrea tulipa* from Ghana, expressed as median values and (min–max).[a]

Location	Benya			Sakumo			Ningo		
	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*
Dry season									
∑Hg	0.21	0.10–0.47	59	0.13	0.08–0.18	25	0.16	0.03–0.23	31
MeHg	0.13	0.03–0.39	54	0.10	0.06–0.23	25	0.08	0.04–0.19	31
Inorganic Hg	0.12	nd[b]–0.41	54	0.03	nd–0.16	25	0.05	nd–0.16	19
%MeHg	54	19– > 100	54	80	39– > 100	25	50	17– > 100	19
Load (μg∑Hg)	0.15	0.06–0.55	59	0.13	0.06–0.21	25	0.10	0.04–0.31	31
Condition index	165	94–342	104	249	211–446	31	203	84–289	31
Length (mm)	47	32–69	104	44	23–71	31	41	27–70	31
Wet season									
∑Hg	0.14	0.10–0.31	24	0.12	0.06–0.23	55	0.13	0.10–0.16	12
MeHg	0.09	0.03–0.24	15	0.05	0.03–0.13	71	0.05	0.04–0.09	5
Inorganic Hg	0.05	nd–0.18	15	0.07	0.03–0.20	45	0.06	0.05–0.09	5
%MeHg	36	17– > 100	15	39	17–68	45	47	40–58	5
Load (μg∑Hg)	0.04	0.03–0.24	24	0.10	0.04–0.17	55	0.07	0.03–0.14	12
Condition index	79	35–281	36	133	99–245	82	146	93–201	12
Length (mm)	34	20–55	36	43	22–70	82	41	21–71	12

[a] *n* = number of samples; inorganic Hg calculated as the difference between total and MeHg. Benya and Ningo: open lagoons; Sakumo: closed lagoon.
[b] nd: not detected.

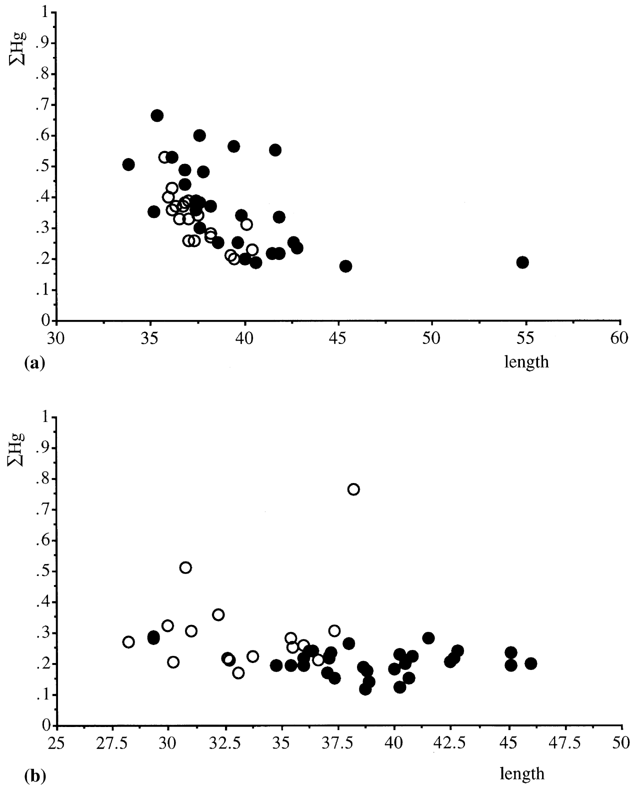

Fig. 3 Total Hg concentration in mussels from Ghana as a function of total shell length; see legend in Fig. 1.

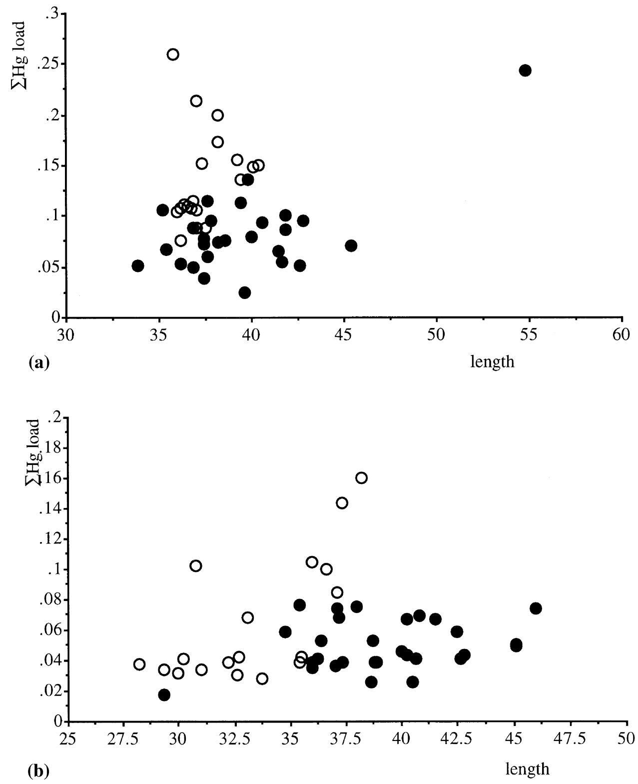

Fig. 4 Total Hg load in mussels from Ghana as a function of total shell length; see legend in Fig. 1.

Ghanaian coast (Ntow and Khwaja, 1989). Apparent seasonal differences (Table 1) were partially due to a heterogeneity in the Benya samples during the dry season (Fig. 1a). The methylmercury concentrations in oysters were also similar to those reported previously for cockles (Joiris *et al.*, 1998), without significant spatial variation ($p > 0.05$). Seasonal differences were significant in the closed lagoon only (Sakumo), the MeHg concentration being higher during the dry season. When expressed as total body load by multiplying concentrations by soft tissue weight, these apparent seasonal and spatial variations of Hg concentration seem to be integrated: total Hg load increases with length, and the spatial difference disappears (Fig. 2). This suggests an influence of seasonal and spatial variations in condition index (Table 1),

TABLE 2

Mercury in the mussel *Perna perna*; see legend in Table 1.

Location	Benya			Sakumo		
	Median	Range	*n*	Median	Range	*n*
Dry season						
∑Hg	0.37	0.19–0.66	30	0.33	0.20–0.53	19
MeHg	0.16	0.07–0.55	35	0.10	0.04–0.18	19
Inorganic Hg	0.13	nd[a]–0.56	30	0.23	0.12–0.35	15
%MeHg	43	12– > 100	30	29	9–50	15
Load (μg∑Hg)	0.08	0.03–0.24	40	0.19	0.08–0.27	19
Condition index	106	48–246	80	158	120–221	32
Length (mm)	38	26–59	80	39	36–40	32
Wet season						
∑Hg	0.20	0.11–0.30	30	0.26	0.17–0.76	18
MeHg	0.09	0.04–0.19	25	0.07	0.03–0.18	10
Inorganic Hg	0.14	0.03–0.22	14	0.16	nd–0.22	10
%MeHg	38	14–79	14	33	28–100	10
Load (μg∑Hg)	0.05	0.02–0.06	30	0.04	0.03–0.16	18
Condition index	125	64–232	58	135	67–252	32
Length (mm)	39	29–46	58	33	28–38	32

[a] nd: not determined.

and renders the former conclusion about apparent spatial differences debatable.

Total Hg concentrations in the mussels showed a decreasing trend with length during the dry season, but not during the wet season (Fig. 3). There was no significant spatial difference ($p > 0.05$), while significant seasonal variations were recorded, with higher $\sum$Hg and MeHg concentrations during the dry season (Table 2; Fig. 3). Once again, when data were expressed as total body load, the effects of season disappeared (Fig. 4).

Metals are more bioavailable in areas of low salinity, freshwater having a higher capacity to maintain metals in the water column either in solution or in suspension than seawater (O'Hara, 1973; Phillips, 1977). Water temperature also can directly influence the rate of Hg uptake by bivalves (Denton and Burdon-Jones, 1981). Differences in primary production could also lead to differences in the Hg concentrations in particulate matter; the higher the phytoplankton biomass (or turnover), the lower its metal concentration for the same level of environmental contamination (Delbeke and Joiris, 1988; Delbeke *et al.*, 1990; Joiris and Overloop, 1987; Joiris *et al.*, 1998).

Finally, the condition index of oysters exhibited seasonal variations (Table 1), which are related to food abundance and or to the period of gonad maturation and spawning before the onset of the wet season (Yankson, 1996). The seasonal and spatial variations observed in this study are thus likely to be due to these various factors. Results on metal contamination in bivalves should therefore not be directly used as reflecting environmental contamination: they should first be normalized for these physical and ecological factors, before any spatial or temporal comparison is attempted.

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