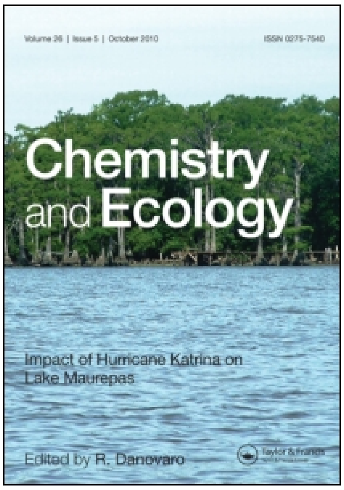

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Heavy Metal Concentrations in Sea Urchin Tissues From Egypt, Ireland and United Kingdom

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HEAVY METAL CONCENTRATIONS IN SEA URCHIN TISSUES FROM EGYPT, IRELAND AND UNITED KINGDOM

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Sea urchins (*Paracentrotus lividus*) were collected from the Mediterranean coast off Alexandria, Egypt and the Atlantic coast of Ireland to the west of Galway. Samples of another urchin species, *Psammechinus miliaris*, were collected from the entrance to Southampton Water, U.K. Both the Alexandria coast and Southampton Water receive domestic and industrial waste water inputs whilst the western Irish coast is relatively unpolluted.

Sampled animals were dissected to separate coelomic fluids, Aristotle's lantern, gonads and tissue (digestive tract plus connective tissue). The concentrations of heavy metals (cadmium, copper, lead, nickel and zinc) in the different parts were measured using flame atomic absorption spectroscopy.

Many levels of heavy metals in the different parts were similar in specimens taken across the wide range of sites and the two species. A notable exception was the high level of copper (33 $\mu g\ g^{-1}$ dry wt.) and zinc 328 $\mu g\ g^{-1}$ dry wt.) in urchin tissue from Southampton Water.

The metal concentrations in the gonads of *Paracentrotus lividus* are of particular interest because of human consumption of this species. The highest levels of copper (3.3–5.2 $\mu g\ g^{-1}$ dry wt.) and zinc (74–181 $\mu g\ g^{-1}$ dry wt.) in gonads were found in the samples from Egypt. Data from this study are compared with other results reported from the Mediterranean.

A simple, short term, elevated water column copper uptake experiment was undertaken with *Paracentrotus lividus* which showed an increase in gonad concentrations of this element.

KEY WORDS: Echinoderm, *Paracentrotus lividus, Psammechinus miliaris*, heavy metals, Mediterranean

INTRODUCTION

Sea urchins are an important species in the shallow sublittoral zones of the Mediterranean, grazing on macroalgae and cyanobacteria. Verlaque (1987), reported that the echinoderm *Paracentrotus lividus* is a determining factor in the dynamics of infralittoral phytobenthos in the Western Mediterranean sea.

The coastal waters of Alexandria receive a large load of heavy metals and organic matter directly through numerous sewage outfalls and from the River Nile. Abdel-Moati (1990, 1991) has calculated that the southeastern Mediterranean waters receive about 110 tonnes of copper and 50 tonnes of lead annually through the Nile River. In semi-enclosed embayments, along the coast of Alexandria pollution has become a serious problem. Seagrass meadows (*Posidonia* and *Cymodocea*), well established feeding, breeding and nursery grounds for large biota, and other algal associations, have been severely damaged (Mostafa, 1991). The remaining algal associations from the main diet for herbivorous molluscs, echinoderms and fish, many of which are collected for human consumption.

The main aim of this study was to determine if there was any evidence for excess bioaccumulation of heavy metals by the echinoderm *Paracentrotus lividus* occurring off Alexandria by comparison with analyses of the same species collected from the Atlantic coast of Ireland which is remote from anthropogenic heavy metal inputs. The concentrations were also compared with those measured in another species, *Psammechinus miliaris*, which occurs in Southampton Water, an industrialised estuary on the central coast of the U.K. Specimens collected from Ireland were exposed to elevated levels of dissolved copper to determine if there was any evidence for short term uptake.

METHODS

During a five month period (October 1992 to February 1993), sea-urchin (*Paracentrotus lividus*) specimens were collected by SCUBA diving from five different localities (El-Shatby, Sidi-Gaber, Gleem, Miami, Montazah) along 15 km of the Mediterranean coast to the east of the harbour of Alexandria, Egypt. At the most easterly sites (Miami and Montazah), urchins were collected from *Posidonia oceanica* seagrass meadows, while for the other sites, specimens were collected from exposed rocky substances.

In April 1993 specimens were collected from three intertidal rocky shores of western Ireland; Black Head and New Quay, 20 km west of Galway and Mace Head 10 km south west of Galway. During the same period another species, *Psammechinus miliaris*, was collected by dredging from the entrance to Southampton Water, U.K.

Fifteen specimens were collected at each site. These were brought to the laboratory in buckets filled with sea water collected from the site of collection. For each specimen, fresh wet weight and diameter of the test were measured, then horizontal bisection performed directly (no depuration was made). Internal coelomic fluids were collected, whilst gonads, tissue (connective tissue and digestive tract) and Aristotle's lantern were dissected out, transferred to acid-washed polypropylene containers and stored frozen. The solid parts were placed in plastic weighing boats and dried in an oven at 80°C for 24 hours to constant weight.

Dissected parts and fluid samples were analyzed for cadmium, copper, lead and zinc. Dried tissue was digested at 80°C for 24 hours in concentrated nitric acid before flame atomic absorption spectrophotometry using a Pye Unicam SP9 AAS. BDH 'Spectrosol' standards were used. Additionally, standard reference material (TORT-1 lobster hepatopancreas, National Research Council, Canada, Marine Analytical Chemistry Standard) was analyzed to check the accuracy of the standards. Results for the range of elements described in this paper were within one standard deviation of the certified values. One blank was included for every 10 samples.

Urchins (*Psammechinus miliaris*) collected from the west coast of Ireland were brought back to the laboratory in Southampton and allowed to acclimatise in sea water for 48 hrs. The sea water used in the laboratory aquarium was collected from Southampton Water and had been allowed to settle in large storage tanks. Uptake experiments were undertaken in static aerated 50 l plastic tanks maintained at constant temperature (20°C). Nine tanks were set up, with three replicates of each of the control (sea water only) and 2 elevated concentrations. The sea water was spiked with BDH 'Spectrosol' copper standard (copper nitrate in nitric acid), 1 mg ml^{-1}) sufficient to increase the original concentration (<1 $\mu g\ l^{-1}$) by 50 and 100 $\mu g\ l^{-1}$.

Fifteen animals were put in each tank and five removed for analysis, as described above, after each day. The animals were not fed.

RESULTS

The wet weight of the urchins (*Paracentrotus lividus*) was related to the diameter of the test. Figure 1 shows separate linear regressions for the results for the specimens from Egypt and Ireland. The data are very similar though the larger Irish specimens tend to be heavier than the equivalent sized specimens from Egypt. This presumably reflects the higher productivity of the Atlantic waters.

Heavy metals concentrations in the different tissues were plotted against the wet weight of the animal to determine if there was any possible correlation. If there is accumulation of excess heavy metals then some parts of older animals might be expected to show higher levels than those in younger, smaller specimens. An example of such a plot with linear regression line is given in Figure 2. The slope of the linear regression line is largely determined by the limited data points from the larger animals. No clear correlation was found for any of the tissues.

The average results of the heavy metal analyses of 15 specimens from each site are summarised in Table I.

Coelomic fluid levels were reported as wet concentration ($\mu g\ ml^{-1}$) and thus were lower than the dry weight concentrations reported for the other tissues. The highest results for cadmium, copper, nickel and lead in the internal fluids are from site E4, El-Shatby, which is the closest to Alexandria harbour. In the case of zinc the highest level was found in urchins from Southampton Water.

Analysis of the lantern showed similar copper results for all sites. Higher levels of cadmium, nickel and lead were found in samples from Ireland and the UK than from Egypt, whilst the opposite was true of zinc.

The most notable feature of the tissue analysis was the elevated level of copper and, to a lesser extent, zinc in the UK Southampton Water samples.

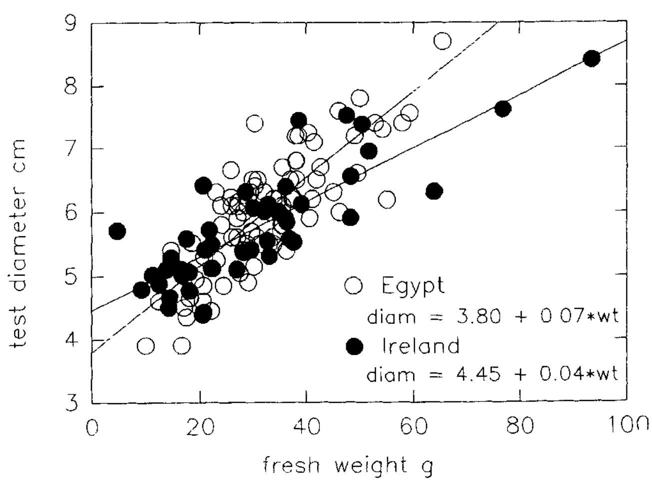

Figure 1 Plot of test diameter against fresh wet weight for specimens of *Paracentrotus lividus* from Egypt and Ireland. A linear regression line is drawn through the data from each country.

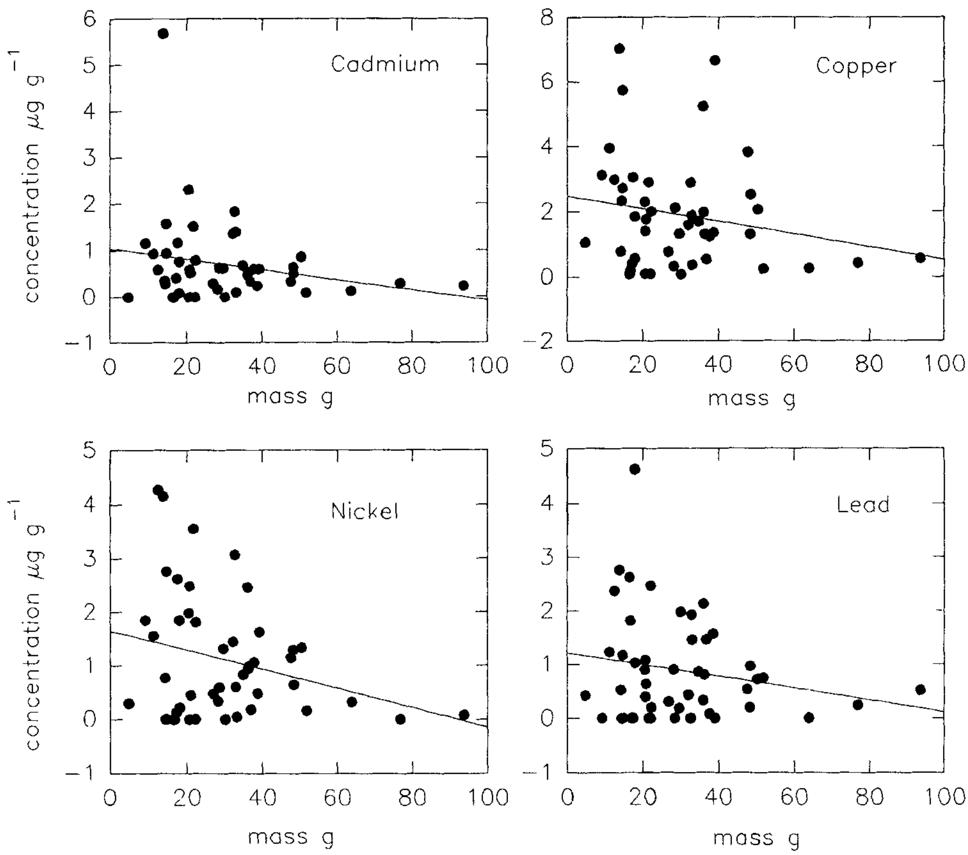

Figure 2 Plot of gonad heavy metal concentration against wet weight of *Paracentrotus lividus* from Ireland with linear regression.

The gonad is the part of the urchin which is eaten by humans and is thus of greater potential interest (Fig. 3). Higher levels of copper and nickel where found in the Egyptian specimens than in those from Ireland. One interesting result is the elevated level of cadmium in specimens from Black Head, Ireland. This site was the most exposed to Atlantic waters, suggesting that this is a feature of local geology rather than of anthropogenic input.

All results from each country have been averaged to provide an overview of the data (Fig. 4). Given the range of countries and that two species have been analyzed the results are remarkably comparable. The most notable feature is the elevated level of copper and zinc in the tissues from Southampton Water. Comparing Egyptian and Irish data, only the lantern results (for cadmium, nickel and lead) are noticeably higher in the he latter and these are raised by the Black Head data.

The elevated levels of copper in the Southampton Water samples suggested the use of this element in the uptake experiments. The experiments were short term as the urchins were not fed in order to avoid the introduction of another variable. Results for the coelomic fluids, tissue and lantern were inconclusive though an

Table I Concentration ($\mu g\ g^{-1}$ dry weight or $\mu g\ ml^{-1}$ for fluids) of heavy metals in different parts of urchins, showing the average and standard deviation of 15 samples from each site.

part	country	site	Cadmium avg	std	Copper avg	std	Lead avg	std	Nickel avg	std	Zinc avg	std
gonad	Egypt	Gleem	0.25	1.28	5.20	2.58	2.82	3.96	9.42	4.64	181.4	97.2
gonad	Egypt	Miami	0.47	0.29	3.53	1.65	2.37	3.94	5.86	2.57	139.1	65.6
gonad	Egypt	Montazah	0.36	0.39	3.26	1.51	0.84	1.31	2.13	2.26	73.7	46.8
gonad	Egypt	El-Shatby	0.36	0.53	4.63	0.81	1.08	1.57	4.72	6.43	103.7	46.3
gonad	Egypt	Sidi Gaber	0.48	0.55	4.78	0.60	2.99	4.77	5.11	2.05	106.0	60.1
gonad	Ireland	Blackhead	1.02	0.66	1.86	0.68	1.20	1.29	1.27	0.88	139.8	170.3
gonad	Ireland	Mace	0.53	0.42	1.84	1.34	0.82	0.90	0.82	0.79	80.6	126.7
gonad	Ireland	New Quay	0.33	0.20	0.70	0.40	0.63	0.46	0.59	0.67	43.1	67.0
gonad	UK	Soton	0.35	0.23	3.81	2.24	0.80	0.97	1.10	1.00	77.6	108.8
fluids	Egypt	Gleem	0.04	0.02	0.14	0.07	0.16	0.17	0.40	0.26	3.6	3.2
fluids	Egypt	Miami	0.07	0.04	0.13	0.09	0.63	0.50	0.38	0.12	3.4	2.4
fluids	Egypt	Montazah	0.15	0.26	0.24	0.35	0.66	1.21	0.95	1.42	0.9	0.4
fluids	Egypt	El-Shatby	0.52	0.44	0.70	0.59	2.53	2.16	2.58	2.11	1.3	0.8
fluids	Egypt	Sidi Gaber	0.05	0.03	0.13	0.04	0.19	0.15	0.30	0.15	1.6	1.5
fluids	Ireland	Blackhead	0.07	0.04	0.28	0.08	0.88	0.24	0.60	0.22	4.9	0.7
fluids	Ireland	Mace	0.10	0.03	0.28	0.25	0.43	0.20	0.36	0.21	5.6	2.0
fluids	Ireland	New Quay	0.03	0.03	0.18	0.11	0.77	0.44	0.54	0.33	4.9	2.8
fluids	UK	Soton	0.21	0.09	0.20	0.10	1.15	0.61	0.97	0.57	58.5	20.3
lantern	Egypt	Gleem	4.39	0.37	5.62	0.48	22.33	2.21	21.42	3.53	21.0	12.3
lantern	Egypt	Miami	4.07	0.72	4.48	1.10	18.88	3.06	18.89	2.95	15.7	6.9
lantern	Egypt	Montazah	4.23	1.09	5.48	1.39	19.96	5.22	18.88	6.45	9.0	1.6
lantern	Egypt	El-Shatby	2.16	1.97	2.90	2.67	10.64	9.59	11.05	9.58	6.3	3.5
lantern	Egypt	Sidi Gaber	4.01	1.16	5.94	0.43	20.63	5.54	21.96	1.36	19.1	13.4
lantern	Ireland	Blackhead	7.23	0.75	5.30	0.30	43.35	4.85	39.85	21.05	2.3	2.1
lantern	Ireland	Mace	6.69	0.56	5.00	0.35	43.38	3.67	34.74	11.25	2.7	2.0
lantern	Ireland	New Quay	5.43	1.42	4.51	0.98	34.15	9.17	28.89	11.55	1.7	2.2
lantern	Ireland	culture	6.99	1.02	5.30	0.88	45.11	5.23	32.49	6.71	0.5	1.0
lantern	UK	Soton	7.55	0.33	6.03	0.26	47.36	1.39	33.87	2.21	1.2	2.0
tissue	Egypt	Gleem	0.36	2.05	6.66	2.47	4.35	5.37	11.36	4.49	198.1	92.1
tissue	Egypt	Miami	2.66	2.44	4.36	1.76	13.09	9.77	14.85	6.54	166.2	89.2
tissue	Egypt	Montazah	1.83	0.62	7.18	1.20	7.63	4.41	9.26	3.42	92.7	40.9
tissue	Egypt	El-Shatby	1.48	1.29	8.19	2.10	11.99	16.83	11.45	10.11	123.7	66.0
tissue	Egypt	Sidi Gaber	2.31	2.26	6.29	1.76	37.96	92.15	13.29	11.00	140.8	94.5
tissue	Ireland	Blackhead	2.61	0.84	6.13	1.45	12.05	6.93	10.30	5.89	134.4	49.1
tissue	Ireland	Mace	2.05	0.69	7.07	1.64	7.19	3.36	7.70	4.37	183.1	63.6
tissue	Ireland	New Quay	1.23	1.57	5.16	10.49	6.82	16.14	5.70	12.68	90.1	178.2
tissue	UK	Soton	1.95	0.49	33.08	4.88	6.80	1.46	6.51	2.16	327.6	119.6

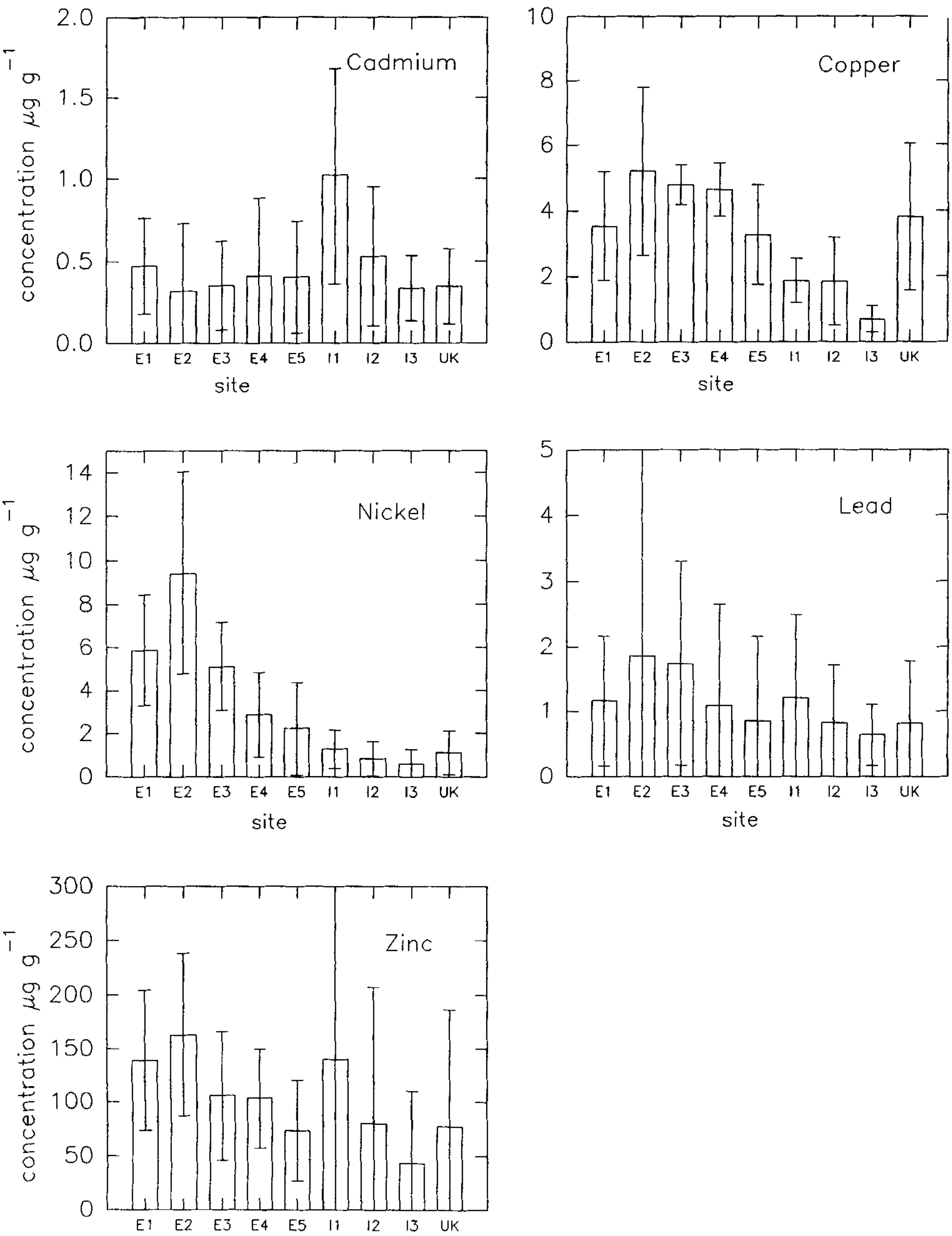

Figure 3 Plot of urchin gonad heavy metal concentration, for *Paracentrotus lividus* from different sites in Egypt and Ireland, and *Psammechinus miliaris* from UK, showing mean and one standard deviation. (E = Egypt, E1 = Gleem, E2 = Miami, E3 = Montazah, E4 = El-Shatby, E5 = Sidi-Gaber; I = Ireland, I1 = Black Head, I2 = Mace Head, I3 = New Quay; UK = Southampton Water).

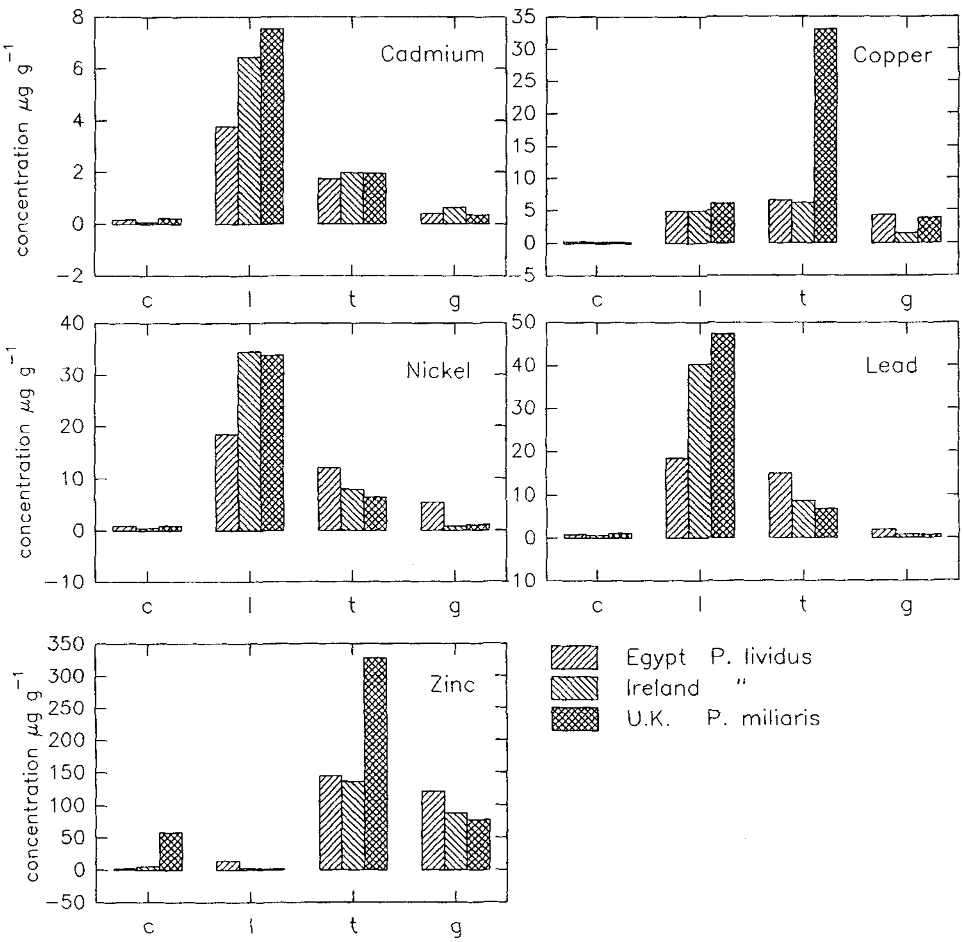

Figure 4 Average (by country) concentrations of heavy metals in different parts of urchins. (c = coelomic fluids, I = Aristotle's lantern, t = tissue (digestive tract plus connective tissue), g = gonad).

upward trend with time can be seen in the gonad concentrations in sea water spiked with 50 μg l^{-1} copper (Fig. 5). Very similar results were obtained with the urchins kept in 100 μg l^{-1} spiked sea water.

DISCUSSION

Overall, the comparability in results from the three different countries has been noted. There are some notable exceptions, particularly the elevated levels of copper and zinc in urchin tissues from Southampton Water. This is an urbanised, industrialised estuary with a major oil refinery. Sediment concentrations of copper as high as 100 μg g^{-1} have been reported by Savari *et al.* (1991). His study examined the concentrations of heavy metals in the cockle *Cerastoderma edule*. No direct correlation between sediment heavy metal load and tissue levels was found but

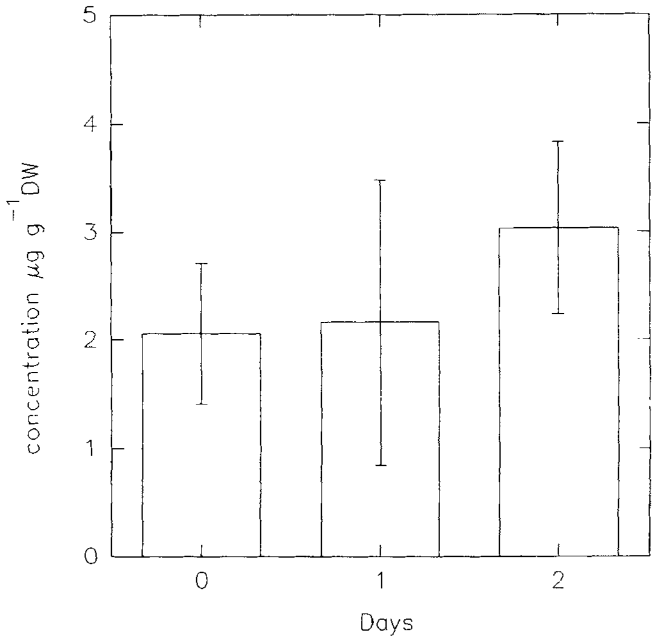

Figure 5 Change with time of gonad copper concentration in *Paracentrotus lividus* kept in sea water spiked with 50 μg l^{-1} dissolved copper.

animal concentrations were generally higher where sediments were contaminated. Tissue copper concentrations ranged from 6 to 32 μg g^{-1}.

In Egypt the urchins from the site (El-Shatby) closest to Alexandria Harbour showed the highest metal ion concentrations in the coelomic fluid. This presumably reflects the high waste inputs to this region. The west coast of Ireland was chosen as a reference site because it is exposed to the Atlantic Ocean and is remote from urbanisation and industrial activity. It is thus surprising that some metal levels, particularly at one site (Black Head), are higher than those from Egypt. This is more likely be a feature of local geology rather than of anthropogenic inputs.

The human consumption of the urchin *Paracentrotus lividus* has prompted a number of studies of the heavy metal content of this species. Augier *et al.* (1989) has measured the levels of cadmium, copper, lead and mercury in samples from four seashore areas around Marseille, France. That study found the highest levels in the parts that are eaten (gonad and digestive tract). The species was sampled subtidally from seagrass (*Posidonia oceanica*) meadows off Marseille by Warnau *et al.* (1993). Their study also examined specimens in this habitat from Calvi, Corsica and Ischia Island, Italy. Of the three locations Calvi was considered to be unpolluted. Gut content was found to be the most representative measure of environmental contamination. However, trends in this measure were paralleled by the gonads and digestive tract concentrations. This led to the conclusion that *Paracentrotus lividus* could be a useful bio-indicator of heavy metal contamination of the sea grass ecosystem.

Catski *et al.* (1991) analyzed animal soft tissues (including *Paracentrotus lividus* gonad), algae and sediments in a baseline study around Milos Island, Greece, in the Aegean Sea. This area was considered by the authors to be unpolluted. Bowen (1979) has collated the reported elemental composition of a wide range of marine organisms including sea urchins though the species are not identified.

Table II compares the gonad concentrations from this study with the other studies above. This shows comparable results from a wide range of sites.

The limited, short term, copper uptake experiment showed a positive response in gonad levels to increased dissolved water column concentration. Longer term experiments with feeding animals would model the field situation more closely.

Table II Comparison of range of heavy metal concentrations ($\mu g\ g^{-1}$ dry weight) in urchin gonad determined in this study with results reported by other workers.

	this study			Augier, 1989	Catski, 1991	Warnau, 1993	Bowen, 1979
	Egypt	Ireland	UK	France	Greece	France/Italy	
	P. lividus	*P. lividus*	*P. miliaris*	*P. lividus*	*P. lividus*	*P. lividus*	
	gonad	gonad	gonad	gonad	gonad	gonad	soft parts
Cd	0.3–0.5	0.3–1.0	0.4	0.1–0.7	2.4–11.4	0.2–0.5	1–9
Cu	3.3–5.2	0.7–1.9	3.8	4.0–6.3	3.7–5.5	2.7–3.2	4–130
Ni	2.2–9.4	0.6–1.3	1.4	–	7.1–34.9	–	0.3–4
Pb	0.8–1.9	0.6–1.2	0.8	0.3–3.1	–	1.4–2.0	0.5–7
Zn	74–163	43–140	78	–	76–127	124–161	68–350

CONCLUSIONS

The comparability in many heavy metal concentrations in different parts of the sea urchins across a range of sites and reported by different workers is interesting. However, there are a number of variations which can be attributed to environmental conditions at different sites. This would support the view that *Paracentrotus lividus* could be used as a bio-indicator of local heavy metals. The study arose from a concern that the pollutant load to the coastal waters of Alexandria, Egypt, may be responsible for excess bioaccumulation by the local sea urchins which are harvested for human consumption. Comparison of the results with other data from the Mediterranean and Ireland suggest that they are not grossly polluted.

Acknowledgement

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