DETECTING LOW-LEVEL SEWAGE POLLUTION USING ROCKY SHORE COMMUNITIES AS BIO-INDICATORS

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While coastal pollution due to high inputs of organic matter is easy to detect and monitor, this is much more difficult in the case of sporadic low-level inputs. Moreover, routine water-quality surveys of large stretches of coastline are time-consuming and often prohibitively expensive. Such monitoring is therefore usually limited to sensitive areas. These restrictions make the results less useful for purposes of coastal pollution management. The indirect assessment of the degree of pollution is thus very appealling (SATSMADJIS, 1985), more so when one can use inexpensive equipment and perennially present indicators. Rocky shore community structure has the potential of being a very suitable indicator of coastal low-level organic pollution: it represents the integrated response of the shore biota to environmental perturbations over time and such communities are readily accessible from the land. The present study evaluates the suitability of using rocky shore community structure as such an indicator in the Maltese Islands. The rocky shore communities at Xghajra, located 1.3 km south of Malta's main sewage outfall and down-current from it, and those at four control sites north of the outfall (Fig.1), were sampled quantitatively by means of 0.5 m x 0.05 m contiguous quadrats along belt transects set perpendicular to the shoreline. Six transects were sampled at Xghajra and one each at the control sites. Faunal species were recorded as number of individuals per unit area and the algae as percentage cover. The data were subjected to a hierarchical cluster analysis using centroid linkage and the Bray-Curtis similarity coefficient for the quantitative data, and the Jaccard coefficient and centroid linkage for the presence/absence data (DIXON, 1988). This was done to correlate the groupings formed with environmental factors.

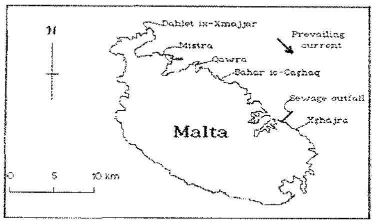

Fig 1. The Maltese islands : the location of Xghajra and the 4 control sites relative to the sewage outfall.

These statistical analyses gave similar results for all the transects, irrespective of the site. Quadrats from each transect were clustered into three distinct groups. The first group contained all the algae and most of the lower shore animals (including *Lepidochitona corrugata, Patella ulyssiponensis, Patella caerulea, Dendropoma petraeum*, etc.). This corresponds to the lower mediolittoral zone of PÉRÈS & PICARD (1964). The second group contained the barnacle *Chthamalus stellatus*, sometimes alone but more often together with one or more other species, such as *Littorina neritoides, Patella rustica, Monodonta turbinata, coralline algae, cyanobacteria* or terrestrial lichens. This corresponds to PÉRÈS & PICARD's upper mediolittoral zone. The third and last group, corresponding to the supralittoral zone of PÉRÈS & PICARD, was composed of the upper shore quadrats with the gastropod *L. neritoides* either alone, as at Xghajra, or together with one or both of the barnacles *C. stellatus* and *C. depressus*. However, Xghajra differed from the control sites in having a higher species richness (Table 1), and a different suite of species (Fig. 2). In particular, Xghajra differed in having a near total absence of the *Cystoseira* cover found on other rocky shores in the Maltese Islands, with only a few stunted specimens of *C. stricta* and *C. compressa* recorded; the absence of species intolerant to pollution (e.g. *Padina pavonica, Acetabularia acetabulum*); and the presence of a large number of pollution-tolerant species (e.g. *Pterocladia capillacea, Corallina elongata, Gigartina acicularis, Ulva rigida, Enteromorpha* spp. and *Cladophora* spp.)

Thus, while the general zonation patterns at Xghajra were similar to those of the four control sites, the shore community here exhibited some peculiarities when compared to the rest, especially in the type of species present and in their abundance. The dominant algae at Xghajra formed associations characteristic of environments having high organic loading in the water as shown in other parts of the Mediterranean and the Red Sea (CORMACI *et al.*, 1985; D'ANNA *et al.*, 1985; ISMAIL & AWAD, 1987; CORMACI & FURNARI, 1991). The presence at Xghajra of a large population of *Mytilaster minimus*, a well known indicator of high nutrient levels (D'ANNA *et al.*, 1985), is indicative of high levels of nutrients in this locality. The chemical analyses carried out in this region confirm this (CHIRCOP, 1992). The type of species, the species richness, their abundance, as well as their associations (especially those exhibited by the algae), at Xghajra, are unusual for Maltese rocky shores and to date have only been found in this area. These results suggest that rocky shore biotic assemblages may be useful indicators of low-level sewage pollution, at least under local conditions.

Location	species richness	algae	animals
Xghajra	65	36	29
Bahar-Ic-Caghaq	21	11	10
Qwara	27	16	11
Mistra	33	22	11
Dahlet-Ix-Xmajjar	32	16	16

Table 1. Comparison of the species richness at Xghajra and the 4 control sites

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		XGHAJRA	CONTROL SITES (GENERALIZED)
TERRESTRIAL ZONE		Inula crithmoides	I. crithmoides
SUPRALITTORAL ZONE		Littorina neritoides; Ligia italica Chthamalus depressus	L. neritoides; L. italica C. depressus
MEDIOLITTORAL ZONE	UPPER	Chthamalus stellatus Patella rustica; Lichens	C. stellatus; P. rustica
	LOWER	Seasonal algal belts (e.g. Enteromorpha spp.) * Monodonta turbinata; Patella spp. Cladophora spp; Mytilaster minimus* Lepidochitona corrugata; Ulva rigida * Fissurella nubecula; Enteromorpha spp * Cardita calyculata; Corallina elongata * Cyanophyceae; Hypnea musciformis * Polychaetes; Gigartina acicularis * Dendropoma petraeum	Encrusting coralline algae Lichens Cyanophyceae M. turbinata Encrusting corallines L. corrugata ; Patella spp Laurencia spp. Dendropoma petraeum
INFRALITTORAL ZONE	(UPPER)	C. elongata *; Pterocladia capillacea * Vermetus triqueter; D. petraeum C. calyculata, Ostrea edulis; M. minimus * Sponges; Bryozoa	Cystoseira spp.; V. triqueter Padina pavonica; Halimeda tuna Pisania striata M. minimus

Fig.2. Comparison of zonation paterns at Xghajra and a generalized zonation pattern for the 4 control sites (* denotes nitrophilous species or species commonly found in degraded or polluted situations

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HEAVY METAL CONCENTRATIONS IN THE DEEP-WATER SHRIMP *ARISTEUS ANTENNATUS* (RISSO, 1816) FROM WEST MEDITERRANEAN (SE SPAIN)

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Mercury, Cadmium, Lead, Copper and Zinc concentrations have been determined in the deep-water shrimp *A. antennatus* (Risso, 1816). Males and females of different size classes were analyzed separately and were sampled from Cabo de Palos and Aguilas, two areas of the coast of Murcia (SE Spain). A high correlation has been found between Hg concentrations and length for females. We have tried to relate the results with biological factors of the species. Specimens were collected in 1991 by commercial bottom-trawl gear seasonallly from April to November from the two sites. Individual shrimps were measured (cefalotorax length), weigthed and dissected. Sex of the specimens was also recorded in the basis of external morphological characteristics. The total number of samples analyzed was 26 corresponding to 193 individuals : 79 males and 114 females. Analyses were performed separately for males and females. All procedures employed in sample preparation and chemical analyses were the usual at the laboratory and have been described before by GUERRERO *et al.* (1988). The concentrations of heavy metal determined for the different areas, year, sex and length of the shrimps are summarized in table I. No significant differences for all metals were found between sites for a given sex and length. Significant differences ($p < 0.05$) in the concentration of mercury between one year old females ($Lc = 25$ mm) and four year old ($Lc > 54$mm) were found. The linear correlation coefficient between Hg concentration in muscle of the shrimps and their length was 0.88 and the determination coefficient shows that the model explains the 78% of the variation found. This pattern of correlation in the case of mercury has been observed in many fish species, mollusca, crustaceans and marine mammals.

It is well known that a number of biotic and abiotic factors can influence the accumulation of trace metals in marine organisms. It is considered unlikely that in this case the levels are affected by environmental factors as discharges from coast, or salinity and temperature of the surrounding waters as they can be considered constant at the depth were the samples were taken. The highest concentrations for cadmium, copper, zinc and mercury were found in November, immediately after spawing when the lipidic and proteic body burden and gonadal composition are lowest (MARTÍNEZ-BAÑOS and ROSIQUE, 1994). This is in accordance also to MANCE (1987), who have reported the occurrence of highest heavy metal concentrations in tissue immediately after spawing. In males the seasonal variations follows the same pattern than in females but no correlation can be established as there is no seasonality in the spawning, and adult males can be found during the whole year (MARTÍNEZ-BAÑOS *et al.* 1992). The high concentrations found in females can be due to their longer life cycle and bioaccummulation period. Generally females can live one year more than males (DEMESTRE, 1990). There are no previous studies taking sex and size of the animal and season of the year into account in relation to metal accummulation for *A. antennatus*. The average values (arithmetic mean for both males and females in each region) lie within the range reported by other authors (HERNÁNDEZ *et al.*, 1986 and GUERRERO *et al.*, 1988) for the Spanish mediterranean area. According to these authors no seasonal variations were found, but in our study high correlation was found between concentration and size.

Table I: Heavy metal concentrations in Aristeus antennatus.

Date	Area	Sex	Nº indiv	Lc (mm)	Weight (g)	µg/g fresh weight				
						Hg	Cd	Pb	Cu	Zn
April	Aguilas	M	6	20±0	3.9±0.3	0.36	0.013	0.079	3.55	9.70
		M	7	25±0	7.1±0.3	0.25	0.009	0.070	4.34	10.53
		F	10	25±0	6.8±0.4	0.35	0.015	0.088	4.63	11.49
		F	11	35±0.5	19±1.2	0.33	0.010	0.079	3.21	10.75
		F	4	54±4.1	54±6.2	0.51	0.010	0.056	3.69	12.72
	C.Palos	M	13	19±0.5	3.8±0.4	0.31	0.008	0,093	3.50	9.91
		M	4	25±0.8	7.0±0.7	0.29	0.012	–	–	–
		F	10	25±0.4	7.7±0.6	0.21	0.010	0.085	2.90	10.16
		F	9	35±0.5	18±0.9	0.47	0.012	0.086	3.16	11.07
July	Aguilas	M	8	22±1.6	5.6±1.1	0.30	0.011	0.058	2.51	10.61
		F	8	25±0.3	7.4±0.5	0.25	0.011	0.054	2.65	12.72
		F	8	35±0.8	17.6±1.6	0.35	0.011	0.052	2.56	13.52
		F	3	59±4.9	61.6±9.2	0.81	0.013	0.045	2.80	11.40
	C.Palos	M	7	19±1.0	3.8±0.5	0.16	0.011	0.092	4.18	10.77
		M	2	28±2.0	9±2.5	0.41	0.020	0.090	2.74	10.29
		F	10	24±0.4	6.7±0.4	0.22	0.010	0.070	2.93	10.83
		F	8	35±0.4	18.2±1.4	0.34	0.007	0.055	2.35	11.71
Nov.	Aguilas	M	8	21±1.2	4.8±0.8	0.23	0.011	0.062	3.20	10.05
		M	6	32±1.1	12.2±1.2	0.53	0.014	0.104	3,21	9.90
		F	6	26±1.1	7.1±1.4	0.27	0.012	0.078	2.18	11.20
		F	10	36±0.4	17.9±0.9	0.38	0.016	0.088	4.21	13.23
		F	3	56±1.6	50.1±3.2	0.87	0.019	0.082	3.45	13.17
	C.Palos	M	8	20±0.4	3.5±0.3	0.59	0.015	0.047	3.08	10.38
		M	10	27±2.3	7.2±1.8	0.70	0.016	0.050	3.12	14.99
		F	10	25±0.7	6.7±0.5	0.38	0.012	0.047	3.98	11.64
		F	4	36±0.8	16.7±0.5	0.55	0.016	0.090	4.94	12.13

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