EFFECTS OF ATHENS POLLUTION OUTFALLS ON MARINE FAUNA OF THE SARONIKOS GULF

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The Saronikos Gulf, on which Athens is situated, receives a considerable load of untreated waste discharges from that metropolis. A survey of ten sublittoral sites shows a marked response by the benthic fauna to the pollution. A much reduced community diversity, coupled with massive increases of certain pollution-tolerant, suspension feeding species indicates a much stressed ecosystem in the North of the Gulf. Selective and gross mortalities of marine species, and states of anoxia which were previously confined to small areas appear to be spreading to larger and more open parts of the Gulf.

INTRODUCTION

The Saronikos Gulf in Greece is considered as a defined ecosystem for pollution studies and is the subject of a multidisciplinary study designed to determine its tolerances to the waste discharges of Athens. This study is sponsored by the Greek Government, the World Health Organisation and the United Nations Development Programme. One of its aims is to assess the effects of wastes on the marine biota of the Gulf.

The Saronikos (Figure 1) is a semi enclosed body of water, roughly 60 km. across and rectangular, with Athens on its northern shore. Being entirely within the continental shelf and nowhere more than 20 km. from a land mass, it is for the most part less than 200 metres deep. The North East or Athens shoreline slopes very gradually to 50 metres deep, while the more central and Westerly parts slope more steeply and sometimes vertically to 50 metres or more. Sewage wastes amounting to 200 million litres/day, mostly untreated, enter into the Eastern basin at the point X (Figure 1); and industrial effluents of a mostly undefined nature enter both the Northern Gulf and Elefsis Bay. In the North particularly, gross effects such as oil fouling and sewage plumes are visible; and water of Elefsis Bay turned anoxic for the first time in the summer of 1973.

This paper describes some of the effects of pollution to be found on the benthic fauna in this section of the Gulf.

METHODS

Sampling was carried out in Spring 1974 with the use of diving equipment. Ten sites in the Eastern Basin (see Figure 1) were sampled, ranging from very close to the main outfalls (sites 1-3) in the North to relatively clean sites near the Southern edge. At each site all material was removed from four quadrats of side 0.25 metres, placed in bags in situ and returned to the laboratory. All fauna above 1 mm. in size were identified and counted. Sampling at all sites was carried out between 4-6 metres deep.

RESULTS

Along the gently sloping Athens shore considerable sedimentation was observed at the more Northerly sites. Elsewhere the degree of sedimentation declined and was absent at the Southern sites. The patterns and directions of the currents are relevant to the dispersion of effluents in the Gulf. They have been summarised to include at least two main modes. A general clockwise movement carries suspended and dissolved materials down the North East Coast; and a smaller circulation cell carries the effluent first to the West along Salamis Island. Alternatively an anti-clockwise movement can occur, again carrying effluent West along Salamis before turning South towards Aegina Island.
The Fauna

From the ten sites a total of 142 species were identified. Of these 101 or 75 percent occurred at only one or two of the sites, and 55 (39 percent) were represented by a single individual.† With this species distribution all analytical techniques based on species presence/absence or association analysis must be meaningless, and emphasis must be placed on more general approaches.

A diversity index is commonly used for elucidating the broad characteristics of a population at a site. Of the many that have been devised the commonest is the $H$ value of Shannon-Wiener, where

$$H_i = - \sum_{j=1}^{s} p_{ij} \log_2 p_{ij}$$

and $p_{ij}$ = number of individuals of the $i$-th species/total number. Diversity thus increases with both an increasing number of species and with a more even representation of each. Figure 2 shows the values calculated for each of the ten sites. A distinct diversity gradient is evident, and values increase with distance from the outfall region.

Figure 3 illustrates the faunal pattern further and depicts the numbers of individual benthic animals at each site in a $\frac{1}{4}$ square metre. Numbers per unit area increase markedly towards the Athens shoreline, reaching enormous densities of well over 500 individuals/$\frac{1}{4}$ square metre in the North. This is amplified in Table I which shows the five most abundant species. It is seen that the increase in animal densities is largely attributable to massive populations of barnacles of the genus Balanus and to a lesser extent to the sedentary polychaete...
**FIGURE 2** Diversity $H$, values for each site. Broken lines distinguish (a) grossly reduced and (b) moderately reduced diversities from (c) the unpolluted high values.

*Protula tubularia.* All are suspension feeding organisms which have been noted for their adventitious behaviour in organically polluted water. The resulting population structure can be very unstable and can only conceivably be supported by a trophic base that has shifted from one of primary production to one of pre-formed organic compounds.

**DISCUSSION**

From Table 1 it can be seen that the most "unbalanced" sites trophically are sites 1, 2, 3 and 5, which are those immediately adjacent to the outfall and along Salamis Island. This conforms with the patterns of currents in the Gulf, since, of the two circulation modes so far observed both carry effluent along Salamis first. The most polluted site both visually and in terms of numbers and diversity was site 3 situated midway along Salamis on a 60° slope to at least 50 metres. Green and brown algae were absent, but some encrusting red forms were present above three metres. The first three metres consisted of a dense bed of *Mytilus*, below which was an equally dense bed of *Balanus* to around 20 metres. From 20–35 metres only dead *Mytilus* shells were found in a layer many cms. thick. This led to a black muddy plateau at 40 metres, of which the redox discontinuity layer appeared to be less than 1 mm. deep. Sampling near here closer to the outfall has shown that the interfacial mud has become anoxic since 1971, a condition which seems to be spreading along Salamis.

The sites along the North East shore responded
FIGURE 3  Numbers of individual animals larger than 1 mm. in any dimension in 1/4 square metre at each site. Broken lines distinguish (a) enormously raised densities, and (b) raised densities from (c) and (d) more normal unpolluted densities.

TABLE I

Five most abundant species and their distribution. Numbers are individuals in 1/4 square metre rock

<table>
<thead>
<tr>
<th>Site/species</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balanus perforatus</td>
<td>299</td>
<td>65</td>
<td>325</td>
<td>66</td>
<td>62</td>
<td>23</td>
<td>20</td>
<td>6</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Balanus tintinnabulum</td>
<td>55</td>
<td>20</td>
<td>51</td>
<td>8</td>
<td>52</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balanus eburneus</td>
<td>8</td>
<td>160</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balanus amphitrite</td>
<td>10</td>
<td>65</td>
<td>21</td>
<td>1</td>
<td>27</td>
<td>5</td>
<td>8</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protula tubularia</td>
<td>10</td>
<td>124</td>
<td>24</td>
<td>27</td>
<td>25</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>372</td>
<td>150</td>
<td>537</td>
<td>87</td>
<td>124</td>
<td>24</td>
<td></td>
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differently to the effluents. At sites 1 and 2 a dense covering of the pollution indicating Ulva lactuca was present down to seven metres. No greater depth was obtained at these two sites. Further South along this shore other species of algae reduced the monopoly of Ulva although the percentage cover of algae remained high. Faunistically, sedentary and errant polychaetes, with molluscs,
increased in proportion, and reduced the dominance of the barnacles. In the Southernmost parts of the Gulf the suspension feeders lost their dominance completely.

Near the outfall and the industrially polluted regions a marked overall loss of species and diversity occurs. A few species appear to both tolerate pollution and exploit it as a food source as is shown by the dominance and relative abundance of these animals. This seems to be the case also with phytoplankton and zooplankton in the Gulf (Yannopolous Unpublished data; Gudenberg Unpublished data).

With effects on the benthic fauna becoming noticeable over 30 km. South and South West of the Athens outfalls, it is to be hoped that the conditions of stress, anoxia and gross mortality at present confined to the North and Elefsis Bay during the Summer will not increase either in extent or duration.

ACKNOWLEDGEMENTS

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REFERENCES