THE USE OF POLYCHAETES AS INDICATORS OF EUTROPHICATION AND ORGANIC ENRICHMENT OF COASTAL WATERS: A STUDY CASE – ROMANIAN BLACK SEA COAST

BY

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The marine eutrophication is one of the most severe problems which affect the seas and oceans worldwide. In the last three decades, as a consequence of the eutrophication and increased organic pollution, at the Romanian coast of the Black Sea major changes occurred in the benthic ecosystems in terms of reduction of biodiversity and modification of distribution of abundances and biomasses. Because the polychaetes are one of the most frequent and abundant components of the marine benthos, the state of their populations can be used to indicate the health of the entire marine environment.

In the last 30 years Black Sea was subjected to enhanced process of eutrophication - the increase of the concentration of dissolved nutrients to a water body (Table 1). This process is followed by intense phytoplankton growth (algal blooming), by organic enrichment of water column and sediments, by oxygen deficiency in the near bottom layers as a result of the bacterial decomposition of the organic matter, and finally by mass mortalities of benthic organisms and production of toxic hydrogen sulphide (Zaitsev, 1991; Gray et al., 2002).

Pearson and Rosenberg (1978) described a general model of effects of organic pollution on benthic organisms. According to this model the first detectable change is an increase in number of species, followed by increase in biomass and subsequently an increase in abundance at relatively high organic matter load (Fig. 1). At higher values of organic load species diversity, biomass and abundance decrease dramatically since anaerobiosis installs.

These authors also suggested four main stages of change in response to organic pollution of the benthos:

1) normal – characterized by the presence of large, deep-burrowing species with deep redox potential discontinuity layer (RPD);

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Table 1. Long-term variation of the mean concentrations of phosphates, nitrates, silicates, and dissolved organic matter (DOM) in Constantza coastal waters (from Petranu, 1997).

<table>
<thead>
<tr>
<th>Period</th>
<th>P-PO₄ (μg l⁻¹)</th>
<th>N-NO₃ (μg l⁻¹)</th>
<th>Si-SiO₄ (μg l⁻¹)</th>
<th>DOM (mgO₂ l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-1970</td>
<td>10.5</td>
<td>22.5</td>
<td>1029</td>
<td>1.96</td>
</tr>
<tr>
<td>1971-1975</td>
<td>177.5</td>
<td>-</td>
<td>1714</td>
<td>2.32</td>
</tr>
<tr>
<td>1976-1980</td>
<td>197.9</td>
<td>188.8</td>
<td>857</td>
<td>2.75</td>
</tr>
<tr>
<td>1981-1985</td>
<td>138.8</td>
<td>93.7</td>
<td>361</td>
<td>2.58</td>
</tr>
<tr>
<td>1986-1988</td>
<td>262.0</td>
<td>112.2</td>
<td>341</td>
<td>2.34</td>
</tr>
<tr>
<td>1988-2000</td>
<td>268.5</td>
<td>114.3</td>
<td>362</td>
<td>2.82</td>
</tr>
</tbody>
</table>

2) transitory – characterized by the presence of smaller organisms, usually deposit-feeding species, which replace large, deep-burrowing species. The RPD layer is shallower;

3) polluted – characterized by a very shallow RPD layer and strong dominance of small tube-building polychaetes, indicates severe eutrophication;

4) very polluted – characterized by sulphide patches at the sediment interface and absence of macrofauna.

Polychaetes play an essential role in the stability and the functioning of the benthic communities of the Black Sea. They are one of the most frequent and abundant groups of marine invertebrates, not only as number of species but also as number of individuals and, in some cases, as biomass (Băcescu et al., 1971; Surugiu, 2002). Because the polychaetes are a major component of the marine benthos, are relatively sedentary (i.e. they can not avoid the pollution), comprise species with different tolerances to stress, and have an important role in cycling the nutrients and other chemicals between the sediments and the water column they can be used as indicators of quality of marine environment.

According to Pocklington and Wells (1992) the strengths of the use of polychaetes in marine environmental quality monitoring are: (1) they are readily available, easy to sample and abundant; (2) they include a great diversity of trophic guilds and reproductive strategies that could be the reason of their success in many environments; (3) they respond to disturbance induced by different kinds of pollution exhibiting quantifiable changes in community structure.

A large number of polychaetes contribute actively to the natural self-purification process. Thus, the suspension-feeding sabellids, serpulids and spirorbids filter large amounts of seawater, freeing it from the suspended particles. Manoleli (1975) estimated that the facultative suspension-feeding species Hypania invalida in 24 hours filters a quantity of sediment which exceeds 9-10 times the volume of the animal proper. Many surface deposit-feeding polychaetes such as spionids, amphiaretids, terebellids, and some nereidids reduce the amount of the organic matter accumulated in the sediment, which is a secondary source of pollution, the organic detritus being strongly transformed...
and incorporated as their own biomass. In this way the polychaetes fasten the circulation of the organic matter from the water column and the sediments into the food chain, without being mineralised. The within-sediment feeding polychaetes such as pectinariids, arenicolids, and capitellids ingest large amounts of mud or sand which then is passed through their digestive tract, playing a similar role to that of lugworms in the aeration of the sediments. This makes possible the activity of aerobic bacteria and contributes strongly to the decomposition of organic substances from the sediments. Gomoiu (1982) deduced that the populations of *Melinna palmata* from the Romanian Black Sea shelf are able to process up to 4.8-9.6 kg of mud/m²/day (!).

Many polychaetes are resistant to pollution. They include a large number of so-called *opportunist species* - species capable of rapid colonisation in strongly disturbed habitats (Grassle and Grassle, 1974). These opportunistic species characterize positively the degree of pollution of water and sediments with organic matter, because they develop in large numbers in the conditions of the reduction of the community complexity in the waters subjected to pollution and eutrophication.
Figure 2. Correlation between the numerical abundance of the individuals of the genus *Capitella* and the organic carbon content of the sediments in the Periboina area

One of the most known opportunistic species is *Capitella capitata* (Reish, 1970; Milovidova, 1975; Grassle & Grassle, 1974). In the Black Sea basin, Zernov (1913) is the first who mentioned this species as characteristic for the most polluted areas of the Sevastopol Bay. On the saprobic scale of Potereaev (1936, cited by Milovidova, 1975) *Capitella capitata* is indicated as being characteristic for α-mesosaprobic waters.

In our research we found that this species has a mean abundance of 785 ind. m\(^{-2}\) and a mean biomass of 0.47 g m\(^{-2}\). We could also observe that the numerical abundance of the species *Capitella capitata* and *Capitella minima* from Romanian Black Sea coast is very strongly correlated (\(r = 0.9703\)) to the quantity of organic matter from the sediment (Fig. 2).

The high value of the coefficient of determination (\(r^2 = 0.9415\)) means that over 94% of the variation in the abundance of *Capitella* species is accounted for by variation in the organic carbon content in the sediment. The significance of the regression line was determined by analysis of variance (ANOVA). The calculated \(F\) value of 48.286 at 1.3 df greatly exceeds the tabulated critical value of 34.116 at these df at \(P = 0.01\), indicating that the linear relationship between the \(x\) and \(y\) variables (regression) is highly significant.

According to Losovskaya (1978) the eutrophication and organic enrichment of the Black Sea had induced the mass development of detritus-feeding species such as *Polydora cornuta*, *Heteromastus filiformis*, *Lagis koreni*, and *Melmna palmata*. Literature records (Tigănuș, 1986, 1990, 1992, 1997) and personal data (Surugiu, 2002, 2003) show that in the period 1980-2000 at the Romanian seacoast the abundances of
The use of polychaetes as indicators of eutrophication and organic enrichment (…)

opportunistic polychaete species such as *Polychaeta cornuta*, *Neanthes succinea*, *Harmothoe imbruecata*, and *Prionospio cirrifera* had increased drastically.

For example, in the present the highest frequency in the samples has the small tube-building species *Polychaeta cornuta*. This species is present at the Romanian littoral with abundances of 6000-22,000 ind. m\(^{-2}\), but in severely polluted areas can reach 95,000 ind. m\(^{-2}\) and a biomass of 157.4 g m\(^{-2}\).

Another opportunistic species – *Neanthes succinea* – which in the recent years became one of the most frequent and abundant species at the Romanian coast (Surugiu, 2002, 2003), has in the open waters a mean abundance of 4300 ind. m\(^{-2}\) and a mean biomass of 16.40 g m\(^{-2}\), while in the severely polluted areas almost at the same abundance (2800 ind. m\(^{-2}\)) the biomass can attain 378 g m\(^{-2}\).

Another category of bioindicators of the quality of marine environment is represented by the so-called sensitive or non-tolerant species, which respond negatively to the increased levels of organic pollution. From this category Bellan (1980) mentions the members of the genus *Syllis* “sensu lato”. In our studies as sensitive species can be considered *Perinereis cultrifera*, *Nereis zonata*, *Syllis gracilis*, *Typosyllis hyalina*, *Nereiphylla rubiginosa*, and *Micronephthys stammeri*, which are found only in the southern part of the Romanian seacoast, where the anthropogenic influence is less. Other sensitive species such *Ophelia bicornis*, *O. limacina*, *Pisoni remota*, *Polygordius* sp., *Glycera convoluta*, *Nephtys cirrosa*, *Magelona rosea*, *M. papilicornis* etc. haven’t been recorded at the Romanian seashore since 70’s.

Because for an accurate assessment of the quality of the marine environment is required the state of the entire community, in the recent years the emphasis is given not to the indicator species but to the indicator communities (Losovskaya, 1983).

Thus, Losovskaya (1977a, 1978) shows that as an indicator of the disturbance of the *Mytilus galloprovincialis* mud community in the north-western part of the Black Sea, as a result of installation in the 90’s mass mortalities of benthic organisms caused by hypoxia and anoxia, could serve the strong impoverishment of the specific composition of polychaetes, characterized by the quasi-total absence of epibenthic species such as *Nereiphylla rubiginosa*, *Harmothoe impar*, and *Pomatoceros triqueter*. An indicator of the recovery of this community is the increase of the proportion of small-bodied deposit-feeding species such as *Spio filicornis*, *Polychaeta cornuta*, *Prionospio cirrifera*, *Capitella capitata*, and *Capitella minima*. As the mussel biocenosis further recovers the relative number of epibenthic species increases, at the expense of small detritivorous polychaetes which are not characteristic for this biocenosis.

Later Losovskaya (1983) proposes for the assessment of the quality of the marine environment the use of the ratio between the total number of capitellids and those of the spionids, the later being the amensals of the former. The numeric prevalence of capitellids over spionids gives the possibility of indirect assessing of the deterioration of the ecological situation for a given marine sector (organic enrichment, installation of hypoxia or anoxia, hydrogen sulphide production etc.). Because many species of spionids are also opportunistic (e.g. *Polychaeta cornuta*, *Streblospio benedicti*, *Prionospio cirrifera*) this method could not provide good results.
For the assessment of the marine environment quality, Bellan (1980) proposes an Annelid Pollution Index (IPA) which represents the ratio between the amount of dominances of so-called “sentinels of polluted water” (e.g. *Platynereis dumerilii*) and the “sentinels of clean water” (e.g. species of the genus *Syllis*). This index is always superior to 1 in the case of polluted environments and inferior to 1 in the case of non-polluted or slightly polluted environments. At the Romanian littoral, this Annelid Pollution Index is always inferior to 1, indicating different degrees of pollution.

Major quantitative changes occurred in the structure of the polychaete assemblages inhabiting hard bottom community with *Mytilus galloprovincialis* from Romanian littoral. For instance, the clogging of the mussel’s interstices with particulate organic matter (POM) and other fine inorganic sediments allows the development on hard bottom of species characteristic for soft sediments like *Prionospio cirrifera*, *Heteromastus filiformis*, and *Capitella minima*, but prevent the settlement of epibenthic polychaete species. Thus, if in the past the epibenthic species *Nereis zonata* had densities up to 2910 ind. m$^{-2}$ (Băcescu *et al*., 1963), at present it became very rare, with an abundance less than 100 ind. m$^{-2}$. This sensitive species was replaced by *Neanthes succinea*, a species which prefers softer sediments and is more tolerant to oxygen deficiency. However, in the last 3 years, we can assist to the gradual replacement of the later by the photophylic species *Platynereis dumerilii*, which is a secondary colonist. This fact and as well as the occurrence on rocky substrate in larger numbers of some sensitive species (*Harmothoe impar*, *Nereiphylla rubiginosa*, and *Syllis gracilis*), indicates the recovery of the hard bottom mussel’s community. Nevertheless, some species abundant in the past, such as *Exogone gemmifera* and *Sphaerosyllis bulbosa*, were completely absent in our samples.

In the aquatoria of seaports Constantza Sud and Mangalia the specific diversity of polychaetes is much reduced. Here we could find only 4 most tolerant to pollution and eutrophication species (*Neanthes succinea*, *Polydora cornuta*, *Ficopomatus enigmaticus*, and *Grubeosyllis clavata*). The large amounts of food available in the form of particulate organic matter have induced an explosive development of these species. Thus, *Neanthes succinea* can reach an abundance of 8000 ind. m$^{-2}$ and a biomass of 378 g m$^{-2}$.

These facts suggest that at present open waters of the Romanian Black Sea coast can be considered as intermediary polluted, while the semi-enclosed bodies of water of seaports are polluted or even very polluted.

**Conclusions**

The polychaetes are a very useful group of organisms in the monitoring of marine environment. The analysis of the polychaete assemblages can be employed with good results to determine the extent and significance of biological effects of pollution. The use of the polychaetes as indicators of natural or anthropogenic disturbance, along with other usual methods (physiochemical and biological), is widely applied in the USA, Canada, Great Britain and Germany.
There is still unsatisfactory knowledge of the biology, ecology and ecotoxicology of many species inhabiting Romanian waters. Also there is very little data on the responses of polychaetes to the environmental disturbances.

Generally, at present the Romanian Black Sea coast is characterised by an intermediary level of pollution, some areas having relatively unpolluted waters (Agigea, Costinesti, Vama Veche – 2 Mai sector) while some areas are polluted (Constantza Sud – Agigea harbour, gulf of Mangalia).

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