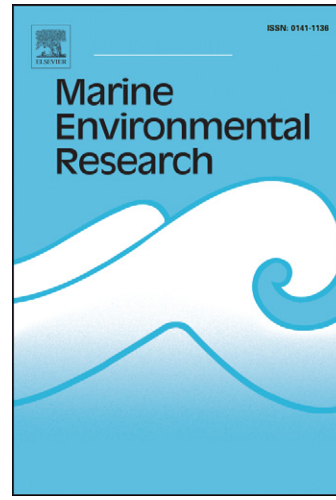
The ecological status of Karavasta Lagoon (Albania): closing the stable door before the horse has bolted?

Cristina Munari, Umberto Tessari, Remigio Rossi, Michele Mistri

Accepted Manuscript



The ecological status of Karavasta Lagoon (Albania): closing the stable door before the horse has bolted?

Cristina Munari, Umberto Tessari, Remigio Rossi, Michele Mistri

PII: S0141-1136(09)00101-9
DOI: 10.1016/j.marenvres.2009.07.003
Reference: MERE 3358

To appear in: *Marine Environmental Research*

Received Date: 26 March 2009
Revised Date: 16 July 2009
Accepted Date: 18 July 2009

Please cite this article as: Munari, C., Tessari, U., Rossi, R., Mistri, M., The ecological status of Karavasta Lagoon (Albania): closing the stable door before the horse has bolted?, *Marine Environmental Research* (2009), doi: 10.1016/j.marenvres.2009.07.003

The ecological status of Karavasta Lagoon (Albania): closing the stable door before the horse has bolted?

Cristina Munari[§], Umberto Tessari[°], Remigio Rossi[§], Michele Mistri[§*]

[§]*Department of Biology and Evolution, University of Ferrara, Via L. Borsari, 46, I-44100 Ferrara, Italy*

[°]*Department of Earth Sciences, University of Ferrara, Via G. Saragat, 1, I-44100 Ferrara, Italy*

Abstract

Karavasta is the widest and most important lagoon in Albania. This study aimed to assess the ecological quality status of the lagoon, acquire knowledge of a natural environment which might be exploited for aquaculture, and give management hints on the basis of anthropogenic impact and ecological conditions. A sampling campaign was carried out in 2008: at six stations, benthic fauna, water and sediment parameters were considered. Statistical analyses were carried out through multivariate procedures (PCA, classification clustering, SIMPER, RDA, DISTLM, PERMANOVA). Ecological quality was assessed through the AZTI Marine Biotic Index (AMBI), the multivariate AMBI (M-AMBI) and the Benthic Index based on Taxonomic Sufficiency (BITS). Sediment characteristics (percent organic matter, %OM; redox potential discontinuity layer depth, RPDL; particle size composition) and salinity represented contributory influences on lagoon communities. It was possible to distinguish and characterise a confined area, and benthic communities, from a marine-influenced area and its biota. The number of species was quite low when compared with other open Adriatic lagoons.

The M-AMBI and BITS classifications gave quite similar results, which seemed consistent with the ecological conditions of the lagoon, that is a distinction in the ecological quality between the seaward and landward stations, with higher ecological quality (EcoQ) at the seaward stations. Given the pressures and the ecological condition of Karavasta, an intensification of aquaculture activities must be considered with caution, since the lagoon seems at significant risk of serious hypereutrophication. This situation is made worse by the limited water exchange with the marine environment due to the irregular dredging of the communication channels.

Keywords: Lagoons; Environmental quality; Water Framework Directive, Albania; Adriatic Sea

*Corresponding author. Tel.: +39 0532 455736; fax: +39 0532 455715.

E-mail address: michele.mistri@unife.it (M. Mistri).

Introduction

Environmental problems in Albania have increased since the last socialist regime (1946-1990), when the economy was centralized by the state and private ownership and activity were not allowed. From 1991, foreign and private enterprises started to compete in food industry, commerce, construction, transport, tourism, and agriculture. This drastic change within the reality of the fragile Albanian economy encouraged the overuse and abuse of the environment, the aquatic ecosystems being the most exposed and unprotected ones. The situation is especially dramatic in the Albanian western lowlands through which flow most of the rivers. This region became heavily populated and large industrial centres and intense agriculture developed. Most urban and industrial waste is disposed without treatment directly into the rivers. Neither liquid nor solid waste is controlled, nor are samples taken regularly of surface and ground water. Monitoring has been irregular and the information given is often not reliable or even contradictory (Cullaj et al., 2005).

Monitoring programs in Albania are neither defined nor operative. Within the framework of an INTERREG programme aimed at the development of aquaculture in selected Balkan water bodies, an ecological assessment of Karavasta, the most important Albanian lagoon, was carried out. This study aimed to (i) assess the ecological quality status of the lagoon considering the benthic system, and according to the Water Framework Directive 2000/60/EC (EC, 2000), (ii) acquire knowledge of a natural environment which might be exploited for aquaculture, and (iii) give management advice on the basis of anthropogenic impact and ecological conditions.

Materials and methods

Study site

The Karavasta complex (40°55'N;19°30'E, Fig. 1), situated in the vast Myzeq coastal plain (western lowlands), is the largest wetland site of Albania. The overall wetland complex, composed of lagoons (Karavasta, Godulla, Spiaxho; ca. 5000 ha), sand dunes and a river mouth, has a surface of 10000 ha. It is situated between the Shkumbini River and Terbufi Canal in the north, and the Canal of Myzeqe and Semani River in the south. In the eastern part the complex is surrounded by Divjaka hills. The Karavasta lagoon is the largest surface (4100 ha) of this wetland complex; it is 15.4 km long and 4.1 km wide. The maximum depth is 1.3 m with an average depth of 0.7 m. The lagoon is divided from the sea by Divjaka pine forest and Godulla lagoon. Agricultural land borders the lagoon. The coastal morphology of Karavasta lagoon was highly dynamic during the last 135 years because of the changes which occurred to the Shkumbini and Semani river deltas (Mathers et al., 1999). The major events occurred when the Semani river changed its course moving northwards in the 1950s, then again southward in the late 1970s. The erosion of its abandoned delta progressively created a spit growing northward, which closed in a few years to form the small Godulla lagoon. Karavasta is connected to the sea via three channels (Brew, 2003). The northern inlet, at present, is completely blocked and disconnected from the sea. The central and southern inlets communicate with the Godulla lagoon, which is connected to the sea by two other shallow channels. The creation of the drainage canals of Terbufi and Myzeqe in the 1980s, together with associated irrigation and drainage schemes, has isolated Karavasta from a significant part of its former drainage basin area. Early in its formation, which goes back to about 1860, the Karavasta lagoon covered double the area it now occupies.

Karavasta is one of the 3 Ramsar sites in Albania: it shelters large quantities of wintering birds and it is also a major nesting site for species of conservation concern, like the Dalmatian Pelican, *Pelecanus crispus* (Peja et al., 1996). Besides its importance as a natural heritage, Karavasta is threatened by several factors. The Shkumbini River was strongly impacted by the Metallurgic Complex of Elbasani: about 30 to 35 million m^3 $year^{-1}$ of liquid waste with a high content of toxic compounds were discharged directly into the river, and about 300,000 tonnes $year^{-1}$ of solid waste were disposed on its riverbanks (Cullaj et al., 2005). Even if the Divjaka urban area is not drained to the lagoon, part of its polluting load discharging from Terbufi Canal may reach the lagoon because its plume is directed mainly southward and close to the coast during spring and summer (Chauvelon, 2004). Sediment analysis from core samples (Crivelli et al.,1996) showed that organic matter made up between 7% and 18% of the dry weight of the sediment and was most prevalent in the sediment of the east and the centre of the lagoon. Hotels, beach bungalows and villas have been recently constructed in Divjaka beach. Construction of numerous bars and restaurants is still taking place in the area, which is visited mainly by local summer tourists, whose number during weekends of August rises up to 8000 visitors per day.

Environmental and biotic data

Logistical constraints forced us to organise only one sampling campaign. For this reason we followed the recommendations of Gray (1981) and decided to sample the lagoon in winter, when population densities are low and there are no settled larvae to count. So, a sampling campaign was carried out in Karavasta lagoon in January 2008, to study structure and composition of the macrobenthic community and to assess the ecological quality status of the lagoon. Sampling stations were selected on two parallel transects drawn along the major axis (NE-SW) of the lagoon (Fig. 1). One station (Stn 1) was placed in front of the central inlet, another station in front of Kryekuq, the only village facing the lagoon. The other stations were almost equally spaced from these two along each transect. The north-easternmost part of the lagoon was not considered because it is an almost emerging mudflat. At each station, benthic fauna was collected in triplicate with a Van Veen grab (area: 0.027

m^2; volume: 4 l) and sieved through a 0.5 mm mesh. In the laboratory, macroinvertebrates were identified at the species level. The benthic community structure was described on the basis of: total abundance of organisms (N), number of species (S), Shannon-Wiener diversity (H'), and Pielou's evenness (J'). At each station, water parameters (salinity, temperature, dissolved oxygen) were collected with an OxyGuard® Mk III probe, and an ATAGO S/Mill-E refractometer. Sediment cores (4.5 cm i.d.) were taken for particle size analysis, and characteristics of the surface sediment were determined in the laboratory by wet sieving and pipette analysis (Folk, 1980). The depth of the redox potential discontinuity layer (RPDL) was recorded *in situ* measuring the depth of the brown layer in sediment plexiglas cores with a vernier calliper. Sediment organic matter content (%OM) was measured as weight loss of dry samples at 400°C for 4 hours.

Data treatment

Principal Components analysis, PCA, (correlation-based transformed and normalized abiotic matrix) was performed for each station using a set of environmental variables, including: sand, silt, clay, dissolved oxygen, RPDL, and %OM. Since salinity showed a strong correlation with sand content, not all of the variables may be needed, and salinity was removed before proceeding with statistical analyses, being effectively redundant for modelling purposes. The following transformations were necessary to reduce the skewness in the variable values: a square-root transformation for dissolved oxygen, and a log-transformation for RPDL, and %OM.

Macroinvertebrate community was investigated by means of classification-clustering based on the Bray-Curtis similarity index and UPGMA sorting of 4th root transformed abundance data. The taxa contributing to dissimilarity between samples were investigated using the similarity percentages procedure SIMPER. The species abundance data were analysed according to the two-factor hierarchical experimental design using permutational multivariate analysis of variance (PERMANOVA, Anderson 2001a; McArdle and Anderson 2001). This approach partitions the variability in the original dissimilarity matrix according to the full multifactorial design, with tests of individual terms obtained using permutations. Measures of multivariate variability at different spatial scales were calculated from the mean squares of the PERMANOVA, using a direct multivariate analogue to the usual ANOVA estimators of variance components (e.g. Searle et al., 1992). We refer to these as measures of 'pseudo' multivariate variation. The statistical significance of each pseudo multivariate variance component was tested using a random subset of 9999 permutations of residuals under a reduced model (Anderson 2001b), with appropriate units being permuted for each term in the design (Anderson and ter Braak 2003). For graphical presentation and comparisons, the variability at each spatial scale is expressed as a proportion of the total variation. That is, for the additive variance components, we have: $\sigma^2_T = \sigma^2_A + \sigma^2_S + \sigma^2_R$, where subscripts indicate total (*T*), area (A), station (*S*), and residual (*R*) or error variability. Differences between community structures in different stations were assessed by permutational non-parametric multivariate analysis of variance (PERMANOVA) according to a one-way experimental design. For the one-way case, an exact P-value was provide using unrestricted permutation of raw data. When low unique values in the permutation distribution were available, asymptotical Monte Carlo *P*-values were used instead of permutational *P*-values.

In order to test how much of the variability in the species/abundance matrix was explained by the set of sediment (predictor) variables, and to find some subset of the variables that are best at explaining variability in the species data, a non-parametric multiple regression analysis was used, under the DISTLM.exe routine (MacArdle and Anderson 2001). For this analysis, each sediment variable was initially analysed separately (excluding other variables) in the marginal test, for testing the potential relationship with the multivariate community (species/abundance) data. Variables were then subjected to a forward selection procedure (sequential test, R^2 selection criterion), where, the amount of variability explained by each variable added to the model is conditional on the variables already in the model. P values for the marginal tests were obtained by using 9999 permutations of the non-normalised and transformed data. Then, the sequential tests were done using 9999 permutations of residuals under the reduced model (Anderson 2001b). All tests were based on Bray-Curtis dissimilarities, calculated among species/abundance observations. Due to the small number of observations for all of these statistical analyses, and according to Geffen et al. (2004), we balanced the possible lack of power to detect effects by interpreting any P-values less than 0.10 as providing some evidence against the null hypothesis. Then, the ordination method of redundancy analysis (RDA) was used to visualise the given model (obtained through DISTLM) between the multivariate community data and sediment predictor variables. The RDA is a constrained ordination used to find linear combinations of the predictor variables which explain the greatest variation in the species/abundance matrix, i.e., it shows the pattern of the species/abundance (response) data as constrained by predictor variables.

Under the hypothesis of latitudinal gradients in the distribution of Mediterranean lagoonal macrofauna (Munari and Mistri, 2008a), the structure and composition of the benthic communities of Karavasta was compared with those of other “closed” Adriatic lagoons, i.e. Lesina Lagoon (which lies at almost the same latitude but on the western side of the Adriatic), Valli di Comacchio (Po River Delta, northwestern Adriatic), and Salina di Comacchio (a hyperhaline environment in the Po River Delta). Comparison was performed through classification-clustering based on the Bray-Curtis similarity index and UPGMA sorting of 4^{th} root transformed abundance data.

All the analyses were performed using PRIMER 6 and PERMANOVA+ β 2.0 (Anderson et al., 2008).

Ecological quality

The AZTI (Arrantzatzuarekiko Zientzi eta Teknology Ikerketa; Technological Institute for Fisheries and Food) Marine Biotic Index, AMBI (Borja et al., 2000), and the multivariate AMBI, M-AMBI (Muxika et al., 2007) were calculated using the freeware program available on www.azti.es (reference conditions status High: AMBI=1.88, Diversity=2.82, Richness=27; reference conditions status Bad: AMBI=5.67, Diversity=0.2, Richness 2). The Benthic Index based on Taxonomic Sufficiency, BITS (Mistri and Munari, 2008) was calculated using the freeware program available on www.bits.unife.it.

Results

Principal Component Analysis showed that for all sampling stations the joined input of the first two axes explained 85.8% of the total variability, so that the 2-d dimensional PCA plot provided an accurate description of the environmental structure in the higher (6-d) space. PC1 accounted for much of the variability (50%) and PC2 most of the remainder (a further 35%). PC1 was essentially a contrast between RPDL depth and sand content (coefficients: -0.568 and -0.506, respectively), and %OM, clay content, and dissolved oxygen (coefficients: 0.393, 0.339 and 0.339, respectively). PC2 accounted for silt content and %OM (coefficient:0.625 and 0.477, respectively) and clay content (coefficient: -0.544). The 2-d PCA showed the separation of environmental responses in 4 groups, with Stns 3, 4, and 5 in the direction of increasing %OM from Stn 3 to Stn 5; what tends to separate stn 6 was increasing silt content and %OM in the sediment. The end points Stns 1 and 2 lied far from each other and there was a trend from Stn 2 to Stn1 of increasing sand and silt content as well as the RPDL thickness in the sediment.

Only 21 taxa (Table 1) were recovered from the 6 sampling stations. Of these, 7 were Mollusca, 5 Annelida, 4 Arthropoda and 5 Nemertinea. Table 2 summarizes community descriptors and environmental values at each station. In contrast to the majority of Mediterranean lagoons (Munari et al., 2009), the number of Annelida taxa was extremely low. Diversity and evenness was higher at Stns 1, 3 and 6. An east–west separation was evident in the classification dendrogram (Fig. 2), where sample-points from seaward sites (Stns 1, 2 and 6) were clearly separated from those from landward sites (Stns 3, 4 and 5). Through SIMPER analysis, a very high similarity within sites 3 and 4 (average dissimilarity = 19.28), and 4 and 5 (average dissimilarity = 9.39), was evident. Landward sites were mainly characterized by the presence in quite high abundance of *Tubificoides swirencowi* and *Chironomus salinarius*. These taxa are generally considered as indicators of reduced hydrodynamism (Castel et al., 1990).

These patterns were confirmed by the PERMANOVA test, showing significant differences among areas (P=0.002) and stations (P=0.001). Altogether, assemblages in the seaward area appeared more heterogeneous than those of the landward area. Indeed, within level “Seaward” of factor “Area”, significant differences were found between Stns 1 and 2 (P=0.024), while within level “Landward” of factor “Area” no differences among stations were found using Monte Carlo tests. Pair-wise tests between stations obtained through the PERMANOVA analysis on one-way experimental design are reported in Table 3. As the number of unique values under permutations was very low, P-values were obtained using Monte Carlo samples from the asymptotic permutation distribution (Anderson and Robinson, 2003).

Table 4 shows the results of the regression analysis performed using the DISTLM *forward* test. The results first show the marginal tests of how much is explained by each sediment variable when taken alone, ignoring all other variables. RPDL depth explains about 43% of the variation in the structure and composition of benthic assemblages. Sediment organic matter, when considered alone, explains ~ 34.8% of the variation. In the conditional test most of the variance of the benthic assemblage was explained by the combination of the following variables: RPDL depth, sand content, organic matter, and silt content accounting altogether for 87% of the benthic assemblage variance.

Fig 3 shows the constrained RDA ordination obtained using DISTLM on the data. The resulting pattern among the stations/samples suggests that there are at least two trends (forming two groups) in the community structure of the macrofauna that can be modelled by these environmental variables. The first clusters Stns 1, 2 and 6, driven largely by the RPDL depth and content of sand in the sediment. The second trend identifies variability among the sites that are in the landward area. These differences are apparently mostly driven by differences in the percentage of organic matter and content of silt in the sediment. The first axis explained 63.1% out of the fitted and 55% out of the total variation, whereas the second explained 19.4% of the fitted and 16.9% of the total variation. Altogether, the first two RDA axes explained 82.5% of the fitted variation, and this was about 71.9% of the total variation in the multivariate community data. All of the RDA axis together explained 100% of the fitted variation and 87.1% of the total variation.

Assessment of the EcoQ of Karavasta derived from different indices for a given station were generally consistent (Table 2). The use of H' resulted in the classification of stations as "Poor" or "Moderate". AMBI was not able to discriminate different ecological conditions, since all stations scored "Good", whereas the use of M-AMBI and BITS rendered different EcoQ for seaward and landward stations, with generally higher EcoQ at seaward stations.

Figure 4 shows the classification dendrogram of Adriatic closed lagoons. Karavasta clusters with northern lagoons instead of, as expected, the southern one.

Discussion

Coastal and lagoonal environments presents high levels of complexity, diverse habitats and supports a high level of biodiversity. These provide goods and services that support different uses which should be undertaken in a sustainable way. Increasing pressures and impacts within European coastal and lagoonal environments have lead to the approval of a series of laws which focus on water management, including the Water Framework Directive (WFD) 2000/60/EC (EC, 2000). At the same time, economic and social pressures for development have lead to the funding of a series of programmes aimed to export a “western model” of aquaculture development in countries from the eastern Adriatic coast (the EU-financed program INTERREG/CARDS-PHARE, AIA: Aquaculture in the Adriatic, carried out by Italy with Croatian, Bosnian, Montenegro and Albanian partners). Karavasta lagoon is facing increasing and significant impacts, whose causes include land reclamation, pollution from hazardous substances and eutrophication, and unmanaged tourism (Cullaj et al., 2005).

This study provided an effective evaluation of the benthic community structure of Karavasta Lagoon. Water and sediment characteristics (e.g. dissolved oxygen, %OM, RPDL, particle size composition) and salinity represented contributory influences on lagoon communities, especially in such a shallow and closed system where salinity for example is more dynamic than the open sea (Perez-Ruzafa et al., 2008). It was possible to distinguish and characterise a marine-influenced area, and benthic communities. The number of species was quite low when compared with open Adriatic lagoons (e.g. Venice; Munari and Mistri, 2008a), but consistent with the species complement of Adriatic closed lagoons (e.g. Comacchio and Lesina; Munari and Mistri, 2008a). Our results were derived from only one sampling period, and thus should be used cautiously, but Beqiraj et al. (2007) reported a very low seasonal variation in the number of macrobenthic taxa in Karavasta, with a total of 17 species in autumn 2004, and 16 species in spring 2005. Relatively few taxa were recorded in some samples (e.g. Stn 5): this may be due to the limited diversity typical of transitional aquatic systems (Cognetti and Maltagliati, 2008) or caused by the patchy distribution of some organisms, especially when present in low numbers. In fact, our faunal list of Karavasta contained fewer Gastropod taxa than that of Beqiraj et al. (2007). Snails may show an aggregate distribution in response to the patchiness of resources (Alfaro and Carpenter, 1999). Benthic species richness and diversity showed variability between stations. According to the confinement theory, a decreasing trend in species richness and diversity should be expected from the less confined to more confined zones in a lagoon (Guelorget and Perthuisot, 1984; Mistri et al., 2000). The finding that species diversity was highest in the confined Stn 3 suggests that environmental stability caused by the presence of even scarce seagrass beds, is probably more important in the case of benthic assemblages than colonization processes.

Historical data on Karavasta lagoon are extremely scarce. Salinity, for example, is reported to show opposing trends for the two main hydrological seasons, with higher summer values because of high evaporation and absence of rain, and lower winter values due to increased rainfall and lower evaporation (Casellato, 1999). In January 2008 we found salinity to be more similar to historical summer values, with values above 50. Increasing salinity is considered as a limiting factor for species diversity (Filippov and Komendantov, 1996), and often some groups of Mollusca are favoured (Vieira and Amat, 1997). As a matter of fact, we found Mollusca to be the dominant taxon in Karavasta. The dominance of Mollusca in the lagoon confirms Beqiraj et al. (2007) preliminary observations. We found Karavasta's benthic communities structure and composition to be more similar to those of macrofaunal assemblages from (polluted and disturbed) northern Adriatic lagoons instead of showing more similarity to those of, for example, the slightly polluted lagoon of Lesina, which lies at almost the same latitude of Karavasta, and whose benthic community structure and composition was expected to be more similar to the Albanian lagoon's because of the latitudinal gradient (Munari and Mistri, 2008a).

In general, low estimates of H' are considered as an indication of environmental stress, with the proposed ecological quality being "High" if H' > 4, "Good" if 3 < H' ≤ 4, "Moderate" if 2 < H' ≤ 3, "Poor" if 1 < H' ≤ 2, and "Bad" if H' ≤ 1 (Vincent et al., 2002). This would mean that all Karavasta stations are, at best, of "Moderate" ecological quality. The biotic index AMBI was created to classify the different coastal and estuarine water masses in accordance with the WFD. Ponti et al. (2008), comparing AMBI with other biotic indices in Mediterranean and Black Sea lagoons, found that the quality assessment provided by those indices was not consistent with the pattern of environmental quality of their investigated sites. The M-AMBI is a multivariate tool, which incorporates AMBI, richness and diversity in the assessment (Muxika et al., 2007). On the basis of several examples of urban and industrial discharges into the Basque Country water bodies, Borja et al. (2008) demonstrated the effectiveness of response of M-AMBI in detecting changes in benthic quality in transition environments. The BITS index is specifically intended for non-tidal and microtidal lagoons, and adheres to the principles of taxonomic sufficiency. The M-AMBI and BITS classifications gave very similar results, which seemed consistent with the ecological conditions of the lagoon, that is a distinction in the ecological quality between the seaward and landward stations, with higher EcoQ at the seaward stations. The finding that BITS gave responses similar to those obtained through the well established M-AMBI could be useful for defining Albanian monitoring programs, in that is easier to use and faster, thus having the potential to save time and money. BITS use may reduce the number of identification errors, and lowers the costs of routine monitoring programs. The cost of family-level identification is

55-63% less (Ferraro and Cole, 1990; Tataranni et al., 2009) than that of species-level identification. Only in the theoretical case in which species of the same genus show different responses to a perturbation, and those species are dominant in the community, would the use of indices based on taxonomic sufficiency (e.g. BOPA: Dauvin and Ruellet, 2007; BITS: Mistri and Munari, 2008) be inappropriate for pollution monitoring (Dauvin et al., 2003).

Today's ecological status of Karavasta seems analogous to that of the Valli di Comacchio 40 years ago, as described by Colombo (1972). That is, an ecosystem (and its biotic communities) which is still resistant to small changes but will move to another "basin of attraction" (i.e. different biotic communities) when perturbed by a larger disturbance (Gray, 1979). The Valli di Comacchio forms a large lagoonal complex in the north-western Adriatic Sea that, over the last 50 years, suffered major anthropogenic impacts, from land reclamation to the effects of contamination of the remaining areas. The Valli have always been an area of intensive economic activity for fisheries. In response to socio-economics pressures, intensive aquaculture activities were developed during the early 1970s but, by the mid-1980s, productive activities and fisheries collapsed (Rossi and Cataudella, 1998) due to the "ecological catastrophe" caused by the hyper-eutrophication of the main basins (Sorokin et al., 1996), and leading to the bankruptcy of aquaculture enterprises. The analogies with Comacchio are historical, economical, and environmental. Both lagoons have a common history of land reclamation, and the intensive reclamation during the former socialist regime led to halve the lagoonal area of Karavasta, with loss of sensitive habitats. From an economical point of view, fishing in Karavasta (as well as for the Valli) is mainly for mullet, sea bass and eel: between the 1980s and the 1990s, the lagoon produced an average of 240 tonnes yr^{-1} (Peja et al., 1996), but, from mid-1990s onwards, production (as for the Valli from mid-1980s) fell sharply. In Comacchio, large meadows of the seagrass *Ruppia cirrhosa* were present in the 1970s (Colombo, 1972), but the extent of coverage dramatically declined in the

1980s (Piccoli, 1998). In Karavasta, Casellato (1999) reported large seagrass meadows in the 1990s, but in 2008 we found only remnants of those meadows in the southern part of the lagoon. Scarce water circulation, sharp temperature and salinity fluctuations, release of toxic substances (especially sulfides) from sediments, and local hypoxic events adversely affected the ecological status of the Valli (Mistri et al., 2000). In Karavasta, summer fish kills have already been observed due to anoxic crisis (Crivelli et al., 1996), and hypoxic events have recently occurred in the inner areas of the lagoon because of algal biomass development (S. Agolli, pers. comm.). The phytoplanktonic community of the Valli changed, in the late 1980s, from diatom-dominated to flagellate-dominated with persistent blooms (Andreoli et al., 1999). Increasing phytoplanktonic flagellates were recently reported for Karavasta (Xhulaj and Miho, 2007). Notwithstanding some signals of recovery (Munari et al., 2005), an ecological evaluation of the Valli through AMBI led to the finding that, out of 28 sites, the commonest EcoQ were "Poor" (10 sites) and "Moderate" (11 sites) (Munari and Mistri, 2008b).

Karavasta is at an important crossroads. On the one hand, a rigorous policy of conservation of this natural heritage is necessary, on the other hand it is also necessary not to disappoint people's legitimate desire of economic recovery. The impact of aquaculture on different environmental typologies has been recently reviewed by Sarà (2007). The ecological effects appeared highly location-specific, and linked to width of the water body and consequently to the hydrodynamic regime. Given the pressures (Cullaj et al., 2005) and the ecological condition (this study) of Karavasta, an intensification of aquaculture activities must be considered with caution, since the lagoon seems at significant risk of serious hypereutrophication. This situation is made worse by the limited water exchange with the marine environment due to the irregular dredging of the communication channels. Our results also suggest that it is important to maintain a freshwater input to the lagoon which is already more salty than sea water, probably during most of the year. The area of Karavasta is subjected to very high coastal dynamics due to sediment discharges and changing morphology of their neighbour river deltas (Ciavola et al., 1999). This will imply some management of its inlets, with subsequent dredging and associated costs. Finally, systematic monitoring programs are urgently needed to follow the ecological quality status of the lagoon.

In summary, the ecological quality of Karavasta lagoon is still acceptable, but the responsibility to protect and use the lagoon properly must be taken most seriously. Taking the appropriate measures in this important and sensitive aquatic environment will help to prevent further damage to biodiversity, and also to humans. Karavasta needs integrated management plans and actions, including not only the lagoon itself but also the entire catchment area and its coastal zone. Such management plans and actions, if suitably implemented by means of appropriate legislation, should ensure the long term functioning and sustainable development of the lagoonal ecosystem. Actions should be drawn up in the very near future, otherwise the lagoon will become so degraded that the cost of restoring will be prohibitive. Albanian authorities have the chance to 'close the stable door before the horse has bolted'.

Acnowledgements

This study was financed by Provincia di Ferrara, within the INTERREG/CARDS-PHARE program AIA: "Aquaculture in the Adriatic". Edmon Mara and Shkelqim Agolli (KEA Foundation, Tirana) are kindly acknowledged for logistical support during our stay in Albania. Two anonymous Reviewers are acknowledged for constructive criticism that greatly improved this manuscript.

References

Alfaro, A.C., Carpenter, R.C., 1999. Physical and biological processes influencing zonation patterns of a subtidal population of the marine snail, *Astrea (Lithopoma) undosa*, Wood 1828. Journal of Experimental Marine Biology and Ecology 240, 259-283.

Anderson, M.J., 2001a. A new method for non-parametric multivariate analysis of variance. Austral Ecology 26, 32–46.

Anderson, M.J., 2001b. Permutation tests for univariate or multivariate analysis of variance and regression. Canadian Journal of Fisheries and Aquatic Sciences 58, 626–639.

Anderson, M.J., Robinson, J., 2003. Generalised discriminant analysis based on distances. Australian &New Zealand Journal of Statistics 45, 301–318.

Anderson, M.J., ter Braak, C.J.F., 2003. Permutation tests for multi-factorial analysis of variance. Journal of Statistical Computation and Simulation 73, 85–113.

Anderson, M.J., Gorley, R.N., Clarke, K.R. 2008. PERMANOVA+ for PRIMER: Guide to Software and Statistical methods. PRIMER-E Ltd., Plymouth, UK., 214 pp.

Andreoli, C., Bresciani, E., Moro, I., Scarabel, L., La Rocca, N., Della Valle, L., Ghion, F., 1999. A survey on the persistent greenish bloom in the Comacchio lagoons (Ferrara, Italy). Botanica Marina 42, 467-479.

Beqiraj, S., Pinna, A., Basset, A., Nikleka, E., Fetahu, B., Doka, E., Ismailaj, M., Barbone, E., Sangiorgio, F., Fedele, M., 2007. Preliminary data on the macrozoobenthos of the Albanian coastal lagoons (lagoons of Patok, Karavasta, Narta). Transitional Waters Bulletin 3, 37-43.

Borja, A., Muxika, I., Rodriguez, G., 2008. Paradigmatic responses of marine benthic communities to different anthropogenic pressures, using M-AMBI, within the European Water Framework Directive. Marine Ecology, an Evolutionary Perspective, in press.

Borja, A., Franco, J., Pérez, V., 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution. Bulletin 40, 1100-1114.

Brew, D.S., 2003. Geomorphology of the Albanian Adriatic coast: A study of short- and long-term changes at Karavasta Lagoon and their implications for coastal management. Geography 88, 88-98.

Dauvin J.C., Ruellet T., 2007. Polychaete/amphipod ratio revisited. Marine Pollution Bulletin 55, 215–224.

Dauvin J.C., Gesteira J.L.G., Fraga M.S., 2003. Taxonomic sufficiency: an overview of its use in the monitoring of sublittoral benthic communities after oil spills. Marine Pollution Bulletin 46, 552–555.

Casellato, S., 1999. Oligochaetes of Karavasta Lagoon (Albania). Preliminary results. Hydrobiologia 406, 175-182.

Castel, J., Labourg, P.J., Escaravage, V., Thimel, A., 1990. Distribution quantitative du meio- et macrobenthos dans des lagunes mixohalines: influence du confinement sur le partage des ressources. Oceanologica Acta 13, 349-359.

Chauvelon, P., 2004. Hydrological functioning and hydraulic management of the Karavasta lagoon system, Albania. FAO, World Bank, Ministry of Environment of Albania, Report 27p.

Ciavola, P., Mantovani, F., Simeoni, U., Tessari, U., 1999. Relation between river dynamics and coastal changes in Albania: an assessment integrating satellite imagery with historical data. International Journal of Remote Sensing, 20, 561-584.

Cognetti, G., Maltagliati, F., 2008. Perspectives on the ecological assessment of transitional waters. Marine Pollution Bulletin 56, 607-608.

Colombo, G., 1972. Primi risultati delle ricerche sulle residue Valli di Comacchio e piani delle ricerche future. Bollettino di Zoologia 39, 471-478 (in Italian).

Crivelli, A., Ximenes, M.C., Grillas, P., Deslous-Paoli, J.M., 1996. *Study on fishery improvement*. European Commission, PHARE programme contract n°95-0161.00: Karavasta lagoon wetland management project, Station Biologique de la Tour du Valat. Arles. 63 pp.

Cullaj, A., Hasko, A., Miho, A., Schanz, F., Brandl, H., Bachofen, R., 2005. The quality of Albanian natural waters and the human impact. Environment International 31, 133-146.

EC, 2000. Directive of the European Parliament and of the Council 2000/60/EC establishing a framework for community action in the field of Water Policy. Available at: http://europa.eu/eur-lex/pri/en/oj/dat/2000/l_327/l_32720001222en00010072.pdf.

Ferraro, S.P., Cole, F.A., 1990. Taxonomic level and sample size sufficient for assessing pollution impacts on the Southern California Bight macrobenthos. Marine Ecology Progress Series 67, 251-262.

Filippov, A.A., Komendantov, A.Yu., 1996. The salinity tolerance of benthic invertebrates of the Aral sea. International Journal of Salt Lake Research 4, 251–263.

Folk, R.L., 1980. *Petrology and sedimentary rocks. 2nd edition*. Hemphill Press, Austin, Texas: 184 pp.

Geffen, E., Anderson, M.J., Wayne, R.K., 2004. Climate and habitat barrier to dispersal in the highly mobile grey wolf. Molecular Ecology 13, 2481-2490.

Gray, J.S, 1981. *The ecology of marine sediments. An introduction to the structure and function of benthic communities*. Cambridge University Press, New York: 185 pp.

Guelorget, O., Perthuisot, G.P., 1984. Indicateurs biologiques et diagnose ècologique dans le domaine paralique. Bulletin Ecologique 15, 67-76.

Mathers, S., Brew, D.S., Arthurton, R.S., 1999. Rapid Holocene evolution and neotectonics of the Albanian Adriatic coastline. Journal of Coastal Research 15, 345-354.

McArdle, B.H., Anderson, M.J., 2001. Fitting multivariate models to community data: a comment on distance-based redundancy analysis. Ecology 82, 290–297.

Mistri, M., Munari, C., 2008. BITS: a SMART indicator for soft-bottom, non-tidal lagoons. Marine Pollution Bulletin 56, 587-599.

Mistri, M., Fano E.A., Rossi, G., Caselli, K., Rossi, R., 2000. Variability in macrobenthos communities in the Valli di Comacchio, Northern Italy, a hypereutrophized lagoonal eco system. Estuarine, Coastal and Shelf Science 51, 599-611.

Munari, C., Mistri, M., 2008a. Biodiversity of soft-sediment benthic communities from Italian transitional waters. Journal of Biogeography 35, 1622-1637.

Munari, C., Mistri, M., 2008b. The performance of benthic indicators of ecological change in Adriatic coastal lagoons: Throwing the baby with the water? Marine Pollution Bulletin 56, 95-105.

Munari, C., Warwick, R.M., Mistri, M., 2009. Monitoring with benthic fauna in Italian coastal lagoons: new tools for new prospects. Aquatic Conservation: Marine and Freshwater Ecosystems 19, 575-587.

Munari, C., Rossi, R., Mistri, M., 2005. Temporal trends in macrobenthos community structure and redundancy in a shallow coastal lagoon (Valli di Comacchio, Northern Adriatic Sea). Hydrobiologia 550, 95-104.

Muxika, I., Borja, A., Bald, J., 2007. Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive. Marine Pollution Bulletin 55,16-29.

Peja, N., Sarigul, G., Siki, M., Crivelli, A.,1996. The Dalmatian Pelican, *Pelecanus crispus*, nesting in Mediterranean lagoons in Albania and Turkey. Waterbirds 19, 184-189.

Peja, N., Vaso, A., Miho, A., Rakaj, N., Crivelli, A.,1996. Characteristics of Albanian lagoons and their fisheries. Fishery Research 27, 215–225.

Perez-Ruzafa, A., Hegazi, M.I., Perez-Ruzafa, I.M., Marcos, C., 2008. Differences in spatial and seasonal patterns of macrophyte assemblages between a coastal lagoon and the open sea. Marine Environmental Research 65, 291-314.

Piccoli, F., 1998. Passato e presente della vegetazione delle Valli di Comacchio. Laguna 5, 24-27 (in Italian).

Ponti, M., Pinna, M., Basset, A., Moncheva, S., Trayanova, A., Georgescu, L.P., Beqiraj, S., Orfanidis, S., Abbiati, M., 2008. Quality assessment of Mediterranean and Black Sea transitional waters: comparing responses of benthic biotic indices. Aquatic Conservation: Marine and Freshwater Ecosystems 18, 62-75.

Rossi, R., Cataudella, S., 1998 La produzione ittica nelle Valli di Comacchio. Laguna 5, 67-76 (in Italian).

Sarà. G., 2007. A meta-analysis of the ecological effects of aquaculture on the water column: dissolved nutrients. Marine Environmental Research 63, 390-408.

Searle, S.R., Casella, G., McCulloch, C.E., 1992. Variance Components. John Wiley and Sons, Toronto.

Sorokin, Yu., Sorokin, P., Gnes, A., 1996. Structure and functioning of the anthropogenically transformed Comacchio lagoonal ecosystem (Ferrara, Italy). Marine Ecology Progress Series 133, 57-71.

Tataranni, M., Maltagliati, F., Floris, A., Castelli, A., Lardicci, C., 2009. Variance estimate and taxonomic resolution: an analysis of macrobenthic spatial patterns at different scales in a Western Mediterranean coastal lagoon, Marine Environmental Research, doi: 10.1016/j.marenvres.2009.02.003.

Vieira, N., Amat, F., 1997. The invertebrate benthic community of two solar salt ponds in Aveiro, Portugal. International Journal of Salt Lake Research 5, 281-286.

Vincent, C., Heinrich, H., Edwards, A., Nygaard, K., Haythornthwite, J., 2002. Guidance on Typology, Reference conditions and Classification System for Transitional and Coastal Waters. CIS Working Group 2.4 (COAST), 119 pp.

Xhulaj, S., Miho, A., 2007 Seasonal data on phytoplankton of some Albanian lagoons. Proceeding of the 3rd Symposium on Mediterranean marine vegetation, RAC/SPA Publ. Tunis, 215-222.

Figure Captions

Fig. 1. Location of the study area, the Karavasta Lagoon (Albania). N.I.: northern inlet; C.I.: central inlet; S.I.: southern inlet.

Fig. 2. Classification dendrogram for standardized fourth-root-transformed macrobenthos data based on Bray-Curtis similarities.

Fig. 3. RDA ordination of the Karavasta data from R^2 model with sediment variables. Percentage of variation explained by individual axes relate to the percentage explained out of the fitted model (i.e. and percentage explained out of the total variation in the resemblance matrix) are reported.

Fig. 4. Classification dendrogram for standardized fourth-root-transformed macrobenthos data based on Bray-Curtis similarities (LES - Lesina Lagoon; COM - Valli di Comacchio; COMU and COML - Salina di Comacchio; KAR - Karavasta Lagoon).

Table 1.

List of species from Karavasta Lagoon. Abundance (ind m^{-2}): *($\leq$ 50), ** (51-100), ***(101-1000), ****(1001-10000), *****(>10001).

	Stn1	Stn2	Stn3	Stn4	Stn5	Stn6
Cephalotrix sp.	*					
Lineus sp.			**			
Valencinia longirostris	*					
Tetrastemma helvolum						*
Malacobdella grossa						*
Bittium reticulatum		**	***			
Hydrobia acuta	****	***	***	****	***	***
Hydrobia ventrosa	*****	*****	****	*****	*****	****
Cyclope neritea		**				
Loripes lacteus	*	*				*
Cerastoderma glaucum	***	***	***	**	**	****
Abra segmentum	****	****	****	****	****	****
Heteromastus filiformis	***	***				***
Arenicola marina		*				
Glycera tridactyla	***	*				
Nephtys hombergi		***				***
Tubificoides swirencowi			***	*		
Ostracoda	****	****	****	****	****	****
Idotea baltica			*	*		
Sphaeroma serratum	***					
Chironomus salinarius	****	***	****	****	****	***

Table 2.

Community, environmental parameters, and ecological quality at Karavasta Lagoon. Community parameters: number of species (S), total abundance of individuals (N, ind m^{-2}), Pielou's evenness (J'), Shannon-Wiener diversity (H', log_e and log_2 based). Water parameters: salinity, temperature, dissolved oxygen (DO) and transparency (as percentage on Stn depth). Sediment parameters: depth of redox potential discontinuity layer (RPDL), sediment composition (percentage of sand-silt-clay), percentage of organic matter (OM%).

Community Parameters	Stn1	Stn2	Stn3	Stn4	Stn5	Stn6
S	12	13	10	8	6	11
N	26103.5	34502.5	9934.5	30414	31727.5	11932.5
J'	0.67	0.39	0.76	0.58	0.54	0.70
H'(log_e)	1.66	1.01	1.74	1.21	0.97	1.67
H'(log_2)	2.39	1.46	2.52	1.74	1.40	2.42
Water Parameters						
Salinity	49	54	54	54	53	51
Temperature (C°)	10.3	10.1	10.3	9.9	9.9	10.1
DO (mg l^{-1})	10.9	11.1	11.9	11	11.1	10.9
Transparency %	92	100	100	100	88	92
Sediment Parameters						
RPDL (mm)	5	3	1	1	1	2
Sand %	20.02	3.72	2.64	1.18	3.72	5.39
Silt %	43.94	35.57	45.35	45.95	42.65	45.28
Clay %	36.02	60.71	52.02	52.87	53.63	49.33
OM %	3.5	1.5	8	7.5	9	6.5
Ecological Quality (EcoQ)						
AMBI	Good	Good	Good	Good	Good	Good
M-AMBI	Good	Good	Good	Moderate	Moderate	Good
BITS	Good	High	Moderate	Poor	Moderate	Good

Table 3.

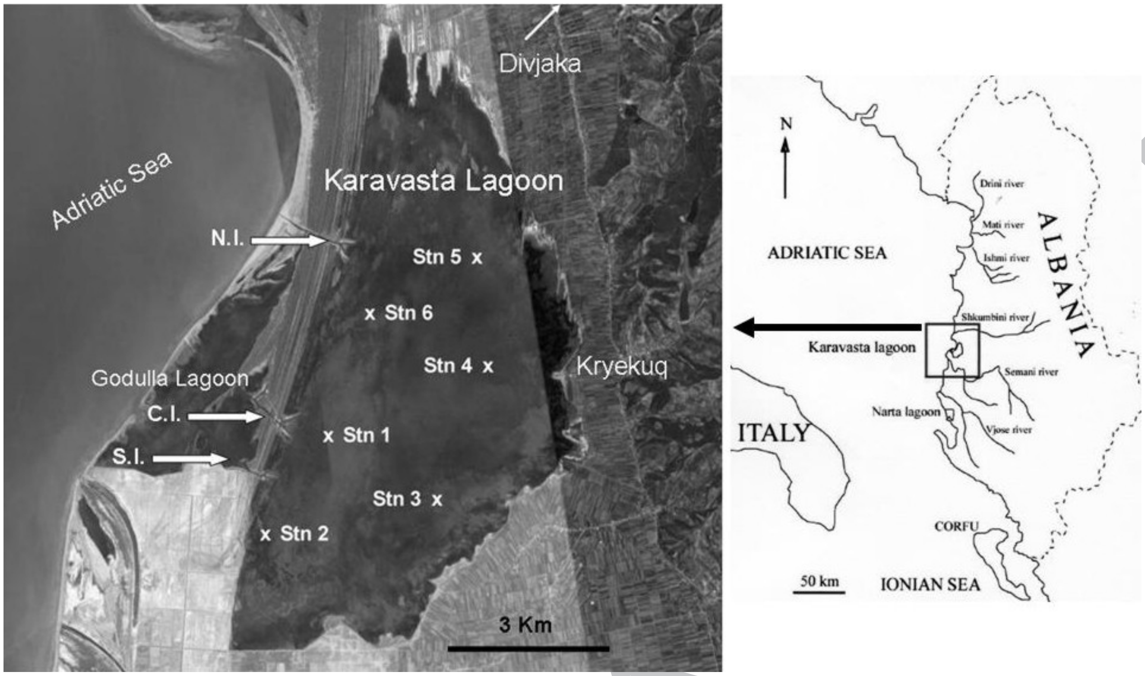
Pair-wise tests from PERMANOVA on unrestricted permutation of raw data. Significant P-values (MC: Monte Carlo test) are in bold.

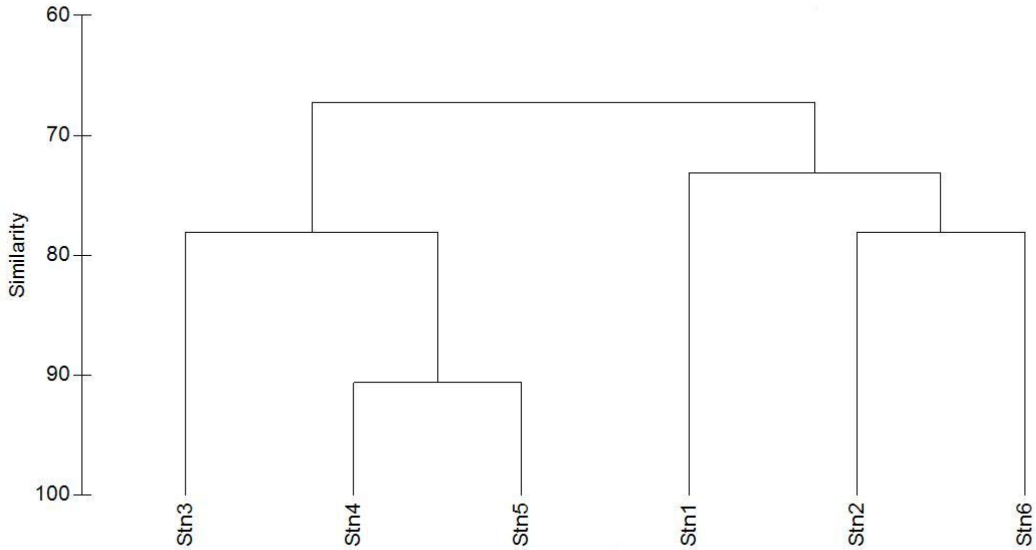
Groups	t	P(MC)
Stn1, Stn2	4.455	**0.025**
Stn1, Stn3	4.159	**0.023**
Stn1, Stn4	2.743	0.058
Stn1, Stn5	3.512	**0.036**
Stn1, Stn6	2.806	0.061
Stn2, Stn3	4.055	**0.024**
Stn2, Stn4	3.121	**0.037**
Stn2, Stn5	3.671	**0.028**
Stn2, Stn6	2.128	0.094
Stn3, Stn4	1.532	0.198
Stn3, Stn5	2.001	0.105
Stn3, Stn6	2.653	**0.050**
Stn4, Stn5	0.528	0.800
Stn4, Stn6	2.373	0.067
Stn5, Stn6	2.538	0.065

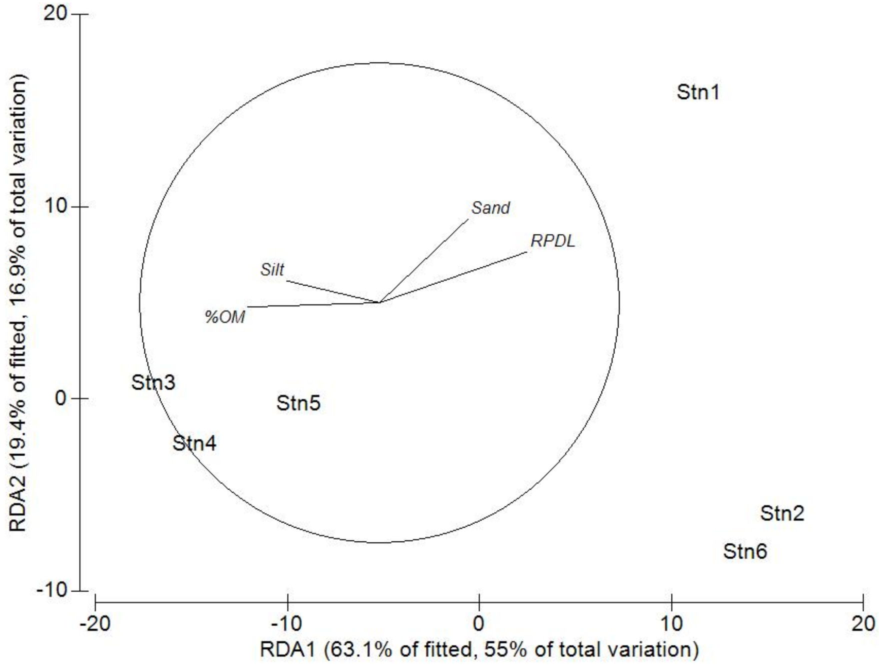
Table 4.

Tests for relationships between the community structure of macrofauna at different stations and several individual sets of sediment variables, using the non-parametric multivariate multiple regression analysis (DISTLM). On the left are the marginal tests of individual sets, on the right are the partial (conditional) tests, where amount explained by each variable added to model is conditional on variables already in the model. P-values less than 0.10 are in bold (%Var: the percentage of the multivariate variance in the community structure explained by that variable; %Cum: cumulative percentage of variance explained; RPDL: redox potential discontinuity layer; %OM: sediment organic matter).

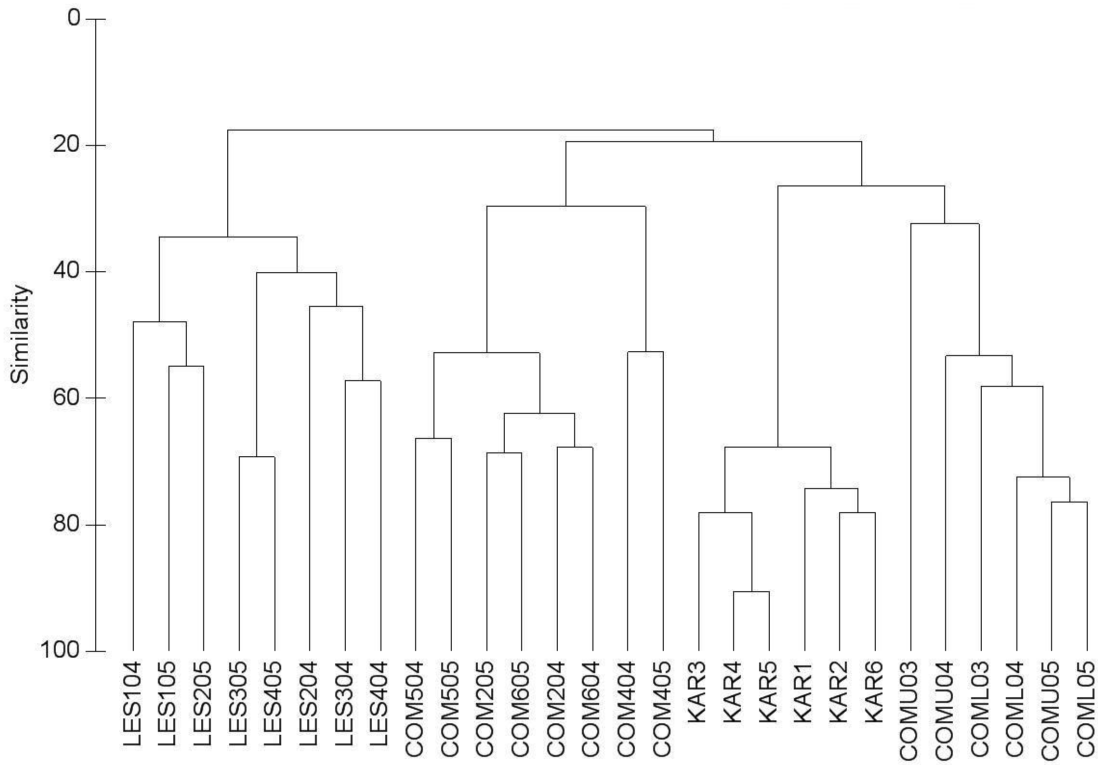
Marginal tests				Sequential tests				
Variable	Pseudo-F	P	%Var	Variable	Pseudo-F	P	%Var	%Cum
RPDL	3.017	**0.059**	42.99	RPDL	3.017	**0.059**	42.99	42.99
%OM	2.134	**0.076**	34.79	Sand	1.611	0.205	19.92	62.91
Sand	1.427	0.175	26.30	%OM	1.626	0.323	16.63	79.54
Silt	1.214	0.325	23.28	Silt	0.589	0.688	7.58	87.12
Clay	0.793	0.640	16.54					


Divjaka
Adriatic Sea
Karavasta Lagoon
N.I.
Stn 5 x
x Stn 6
Stn 4 x
Kryekuq
Godulla Lagoon
C.I.
x Stn 1
S.I.
Stn 3 x
x Stn 2
3 Km
N
ADRIATIC SEA
ALBANIA
Drini river
Mati river
Ishmi river
Shkumbini river
Karavasta lagoon
Semani river
Narta lagoon
Vjose river
ITALY
CORFU
50 km
IONIAN SEA


Similarity
60
70
80
90
100
Stn3
Stn4
Stn5
Stn1
Stn2
Stn6



20
10
0
-10
-20
-10
0
10
20
RDA2 (19.4% of fitted, 16.9% of total variation)
RDA1 (63.1% of fitted, 55% of total variation)
Stn1
Sand
RPDL
Silt
%OM
Stn3
Stn5
Stn4
Stn2
Stn6


Similarity
0
20
40
60
80
100
LES104
LES105
LES205
LES305
LES405
LES204
LES304
LES404
COM504
COM505
COM205
COM605
COM204
COM604
COM404
COM405
KAR3
KAR4
KAR5
KAR1
KAR2
KAR6
COMU03
COMU04
COML03
COML04
COMU05
COML05