Transitional Waters Bulletin
TWB, Transit. Waters Bull. 1(2007), 77-82
ISSN 1825-229X, DOI 10.1285/i1825229Xv1n1p77
http://siba2.unile.it/ese/twb

RESEARCH ARTICLE

Eleven years monitoring of Lesina lagoon (South Italy) using a biotic index (L)

Breber P., Cilenti L., Scirocco T.

Consiglio Nazionale delle Ricerche,
Via Pola 4, 71010 Lesina (Fg), Italia.
Tel. +39 0882 992705, Fax +39 0882 991352,
e-mail paolo.breber@fg.ismar.cnr.it

Abstract

1 - The scope of our work was to assess the ecological status of Lesina lagoon on the South Adriatic coast of Italy according to the biological priorities expressed by the directives of the government, priorities which can be summed up in the key words of bionomics, biomass and biodiversity.

2 - Our method was based on the characteristics of the sessile benthic macrofauna considered to be indicative of environmental status. We developed a biotic index (Λ) that grades from 1 to 10 the rising quality of the environment. The data required for applying the index, i.e. spatial distribution (Zonation), biomass (g ww/m2) and number of species of the benthic macrofauna, were obtained from samples of sediment taken at systematically distributed stations over the entire surface of the lagoon. Samples were taken in spring and again in autumn.

3 - Our first assessment in Jan. 1993 gave 8.48, a high value. No samples were taken in 1994 but quality probably remained high because in Nov. 1995 the index gave 7.86. In 1996 quality must have begun to decline because although we took no sample in that year, in May 1997 the index was 6.14, which is very low for spring, when quality is normally high. The situation did not improve until August 1998 when the index rose to 7.59. From then on till our last assessment in Oct. 2003 the environmental quality of Lesina was at a stable high, the index registering values above 7.00 with a peak of 8.15 in Aug. 1999.

4 - The index values that we registered closely coincided with the opinion on the state of the environment given by experienced fishermen whose livelihood depends on the quality of the lagoon.

Keywords: Adriatic, Lesina lagoon, environmental quality, index, benthos, biodiversity, biomass, productivity

Introduction

The scope of the present work was to assess the ecological status of Lesina lagoon on the South Adriatic coast of Italy according to the biological priorities expressed in the policy statements of the government, priorities which can be summed up in the key words: biodiversity, biomass and productivity.
Environmental policy considers the quality of lagoons from two viewpoints: pollution and ecological status. Unlike other bodies of water (lakes, rivers, seas), in lagoons anthropogenic pollution is not the only determinant of ecological status because one must consider the concurrent factor of the natural variability of the ecosystem. A lagoon quite unaffected by anthropogenic pollution may present a variety of ecological situations which would be judged negatively from a human point of view. Excessive fluctuations in salinity, harmful microalgal blooms, anoxic crises, too much or too little marine penetration and excessive turbidity are examples of negative conditions which may arise from purely natural causes (Breber, 1997). What is therefore the definition of quality in a coastal lagoon? We have derived the notion of environmental quality from the

directives of the government which are thus briefly summarised.

The milestone in Italian government policy with regard to lagoons and wetlands in general is the signing of the Ramsar Convention (1971). This convention recommends the conservation of wetlands for their function as "regulators of water regimes and as habitats supporting a characteristic flora and fauna, especially waterfowl." It stresses their "great economic, cultural, scientific and recreational value." The value of biodiversity is implied in the concern for "flora and fauna" and "waterfowl." The economic value of lagoons lies mainly in the fishery and extensive aquaculture which are a reflection of productivity and biomass. The recreational value of lagoons, i.e. tourism, lies in the natural landscape and in the birdlife which again are related to biodiversity. A subsequent acknowledgement by the Italian government of the need to safeguard lagoons is found in the Legislative Decree of 11th May 1999 (n°152), on the protection of waters. This document requires that, in assessing the quality of a lagoon, it is not sufficient to investigate for pollutants but an appreciation of the biodiversity is also necessary and a study of the phytoplankton, macrophytes and benthic macroinvertebrates is suggested. Although mainly concerned with waters for direct human use (domestic, irrigation, industry, transport, power), the Water Framework Directive 2000/60/EC also considers ecological status for its own sake. N° 17 of the preliminary statements of intent has a special word for lagoons: "An effective and coherent water policy must take account of the vulnerability of aquatic ecosystems located near the coast and estuaries or in gulfs or relatively closed seas, as their equilibrium is strongly influenced by the quality of inland waters flowing into them. Protection of water status within river basins will provide economic benefits by contributing towards the protection of fish populations, including coastal fish populations." The economic benefits deriving from lagoon fisheries depend on the level of biomass and productivity within the ecosystem. Biodiversity is taken into account when the WFD prescribes the study of the vegetation, benthic macrofauna and fish fauna (Annex V; 1.1.3). With these directives in mind we proceeded to undertake a study of Lesina lagoon.

This coastal body of brackish water covers 6000 ha and is only 1 m deep (Fig. 1). It communicates with the sea through two artificial channels and receives freshwater from karst springs and also from the sewage treatment plants of three towns within the drainage basin. The salinity variations are pronounced and present a permanent E-W gradient due to the fact that all the freshwater input occurs at the eastern end. The lagoon may be defined as polyhaline. The annual temperature cycle has extremes of about 5° and 30°C. The fishery of Lesina yields seabass, gilthead, grey mullet and silverside, but is famous for its eel.

Methods

For assessing the ecological status of Lesina lagoon we have developed a relatively simple biotic index (Λ) based on the characteristics of the benthic macrofauna (Breber *et al.*, 2001) and inspired by the work of Vatova (1951; 1953) and Frisoni *et al*. (1984).

After investigating the lagoons and fish-farming meres ("valli da pesca") of Italy, Vatova (1951; 1953) was the first to correlate environmental quality, essentially interpreted as the natural capacity for fish production, with the characteristics of the benthos (Breber *et al.*, 2000). Later and independently, Frisoni *et al.* (1984) arrived at the same conclusions as the result of a study of fifteen lagoons in southern France, Greece, Morocco and Tunisia. These authors distinguish different sub-assemblages within the general bionomic category of

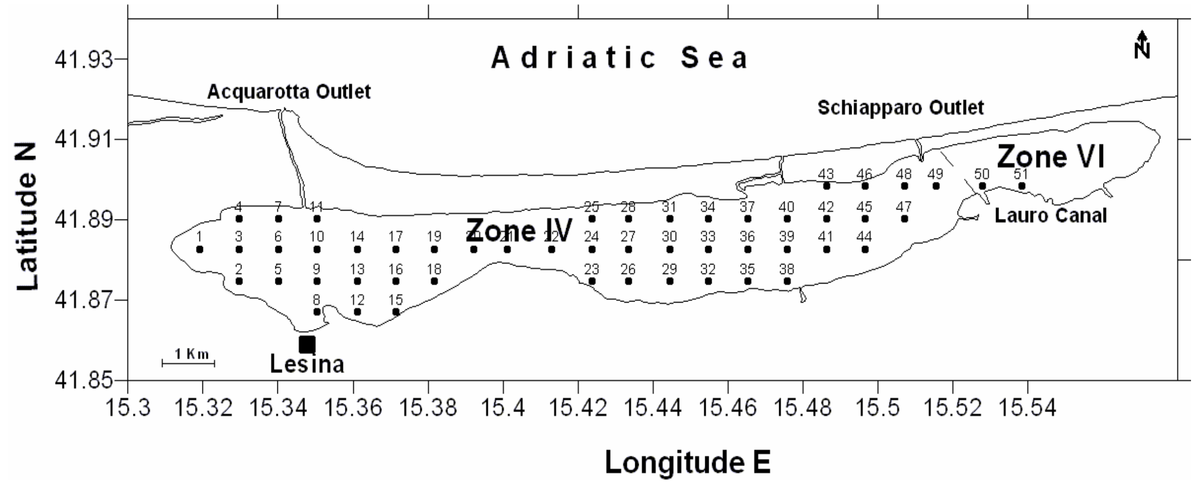

Fig. 1. Lesina lagoon showing sampling stations (dots) and zonation according to Frisoni et al. (1984).

Mediterranean coastal lagoons as defined by Perès and Picard (1964) ("Biocoenose lagunaire euryhaline et eurytherme"). They identified six possible benthic sub-assemblages (Zones) which succeed one another along the gradient of marine penetration into the basin. Biodiversity diminishes proceeding from Zone I nearest the sea channel, to Zone VI ecologically the farthest from the sea. Biomass and productivity reach the maximum halfway along the gradient, in Zones III and IV. Bivalves are the most useful organisms for recognising the zonation. Zones I and II contain species which are still basically marine and not particularly euryhaline, such as *Chamelea gallina* Linné, 1758; *Mactra stultorum* Linné, 1758; *Donax trunculus* Linné, 1767; etc. Typical lagoon species appear in Zone III and IV. *Loripes lucinalis* Lamarck, 1818; *Tapes decussatus*, *Anadara polii* Mayer, 1868 and *Gastrana fragilis* Linné, 1767 are some of the commonest belonging to Zone III. The number of bivalve species declines drastically in Zone IV, mostly limited to *Abra alba* Wood, 1802, *Cerastoderma glaucum* Poiret, 1789, and *Mytilaster minimus* Poli, 1795. There are no bivalves in Zone V, where the only benthic macrofauna consists of arthropods, gastropods, polichaetes and chironomid larvae. This zone is the most subject to summer anoxia, during which the benthic macrofauna is temporarily wiped out. Zone VI is very marginal, being either a place where continental water flows in, in which case the benthos is freshwater, or a stagnant evaporitic embayment with hyperhaline conditions and no benthic macrofauna.

Zones III and IV present the most favourable combination of biodiversity, biomass and productivity, and are considered the most productive in terms of extensive aquaculture and fisheries. Thus the lagoons with the highest environmental quality according to the conservation laws, and which we consequently take as reference condition, are those in which Zone III and/or Zone IV occupy the greatest possible area.

Our Index Λ assesses a lagoon on the basis of the above conceptual scheme. The procedure entails measuring the relative extent of the Zones, and the number of species and the mean biomass (g wet weight/m^2) of benthic macrofauna present in each. A box-corer with a 15 x 15 cm opening was used to gather the samples, and the material was sorted on a 1 mm mesh. Each sample consisted of 53 sampling units taken from as many stations (Cuff and Coleman, 1979), distributed according to a systematic grid (Fig. 1). The plan was to take two samples a year, one in spring and one in autumn, in order to register the effects of the two critical seasons of winter and summer, but this was not always possible.

Having obtained the three metrics, the index was then calculated by applying them in the following formula.

$$\ln\left(\sum_{i=1}^{6}\frac{n_i}{N}\bullet b_i\bullet S_i\bullet t_i\right)=\Lambda$$

Where i identifies the Zone (I, II, III, IV, V, VI);

n_i is the number of sampling units ascribable to Zone i;

N is the total number of sampling units comprising the sample;

b_i is the mean biomass (g ww/m^2) in Zone i;

S_i is the number of species in Zone i;

t_i is the ratio of productivity to biomass and for the practical purposes of the index may be considered 1 (Brey, 1990).

Λ expresses the ecological state of the lagoon according to a scale of increasing quality from 1 to 10.

Results

We took isolated samples in 1993 and 1995. When we began regular activity in 1997 the lagoon was in the phase of a dense green microalgal bloom, possibly triggered by the quite extraordinary heavy rain of the preceding summer that caused nutrient run-off from the surrounding fields. From May 1997 to January 1998 the index stayed below 7.00 due to the persistence of the bloom (Fig. 2). In August 1998 the bloom had disappeared and as a result the quality rose to 7.59. February 1999 registered a slight dip to 7.17 but then in the subsequent August the index rose to 8.15, which is high. In Feb. 2000 the index decreased somewhat to 7.42, which can still be considered satisfactory. The lagoon stayed around these values to October 2003. In 2004 we did not take samples. When we resumed the work in 2005 the index registered 8.15 in May, showing that the quality was again rising.

After recovering from the bloom in 1998, the quality of Lesina remained consistently high. Being a very shallow basin (< 1 m deep), oxygen diffuses readily, preventing anoxic conditions even at the height of summer conditions. During the period of the bloom from 1996 to May 1998, 90% of the lagoon presented the characteristics of a Zone V. The remaining 10% was a Zone VI at the eastern extremity consisting of a freshwater area. The sample of August 1998 revealed that the situation had improved: the Zone V had disappeared and a Zone IV had taken its place.

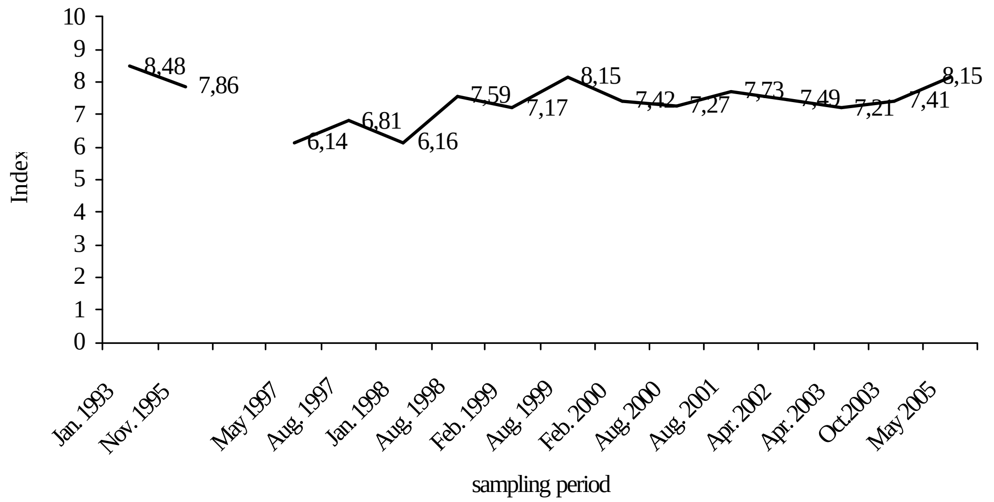

Fig. 2. Variations in environmental quality over time as registered by Biotic Index Λ.

Discussion

The record over a span of twelve years shows that the bionomics of the lagoon are not stable and are apparently heavily influenced by the weather. The variations appear to be oscillations around a typical modal state to which the ecosystem always tends to revert. The modal condition of Lesina may be described as a homogeneous Zone IV having a limited freshwater Zone VI at the eastern extremity (Fig. 1), with Λ consistently above 7.00 (Fig. 2). The drop in quality from May 1997 to January 1998 appears to have been a passing phase, due to a lingering dinoflagellate bloom that developed during the very rainy summer of 1996, from which the ecosystem emerged in August 1998 to settle in its modal state.

We found that our assessment of the state of the lagoon closely corresponded to the opinion of the fishermen whose livelihood depends on the quality of the environment. For Lesina we took into consideration the catch of gilt-head (*Sparus aurata*), which is the fish that reacts most quickly to changing conditions in the lagoon. It feeds mainly on the benthos, with a preference for bivalves (Breber and Strada, 1995), and it reaches commercial size within one year. In the bad years (Λ < 7.00) of 1997-8 only about 50 tonnes/y were caught, whereas in the good years (Λ > 7.00) the catch averaged 275 tonnes/y (Breber *et al.*, 2000).

Other biotic indices based on benthic macrofauna, proposed by various authors (Engle *et al.*, 1994; Grall and Glémarec, 1997; Weisberg *et al.*, 1997; Borja *et al.*, 2000; Eaton, 2001) for assessing the environmental quality of in-shore coastal and estuarine waters, are not applicable to coastal lagoons. These indices are aimed at detecting pollution and consider the organic enrichment caused by it to be the key negative factor influencing the characteristics of the benthic assemblage. The gradual changes observed in coastal benthos determined by increasing levels of organic pollution of human origin (Pearson and Rosenberg, 1978) are very similar if not identical to the Zonation of the lagoon benthos described by Frisoni *et al*. (1984), which these authors consider to be the result of the purely natural phenomenon of "confinement", i.e. the degree of marine influence penetrating into the lagoon. The accumulation of dead organic matter in the sediment is, in fact, a natural process in coastal lagoons, so that one cannot really distinguish between the organic matter from natural eutrophication and the organic matter generated by pollution from domestic sewage and agricultural fertilisers. Actually, this type of pollution is not necessarily harmful if it expands Zones III and/or IV at the expense of Zones I and II; but it is, of course, harmful if it creates or increases a Zone V.

We find that our Index Λ is useful for monitoring the variations in the quality of the environment caused by such factors as excessive fluctuations in salinity, harmful microalgal blooms, anoxic crises, too much or too little marine penetration and excessive turbidity. Such variations may have human causes (e.g. domestic sewage, agricultural fertilisers, dredging and embanking, etc.) but they may also derive from the natural dynamics of the ecosystem, or from both together. The Index is not suitable for detecting pollution from toxic substances (heavy metals, pesticides, etc.) at sub-lethal levels where chemical analysis is essential.

References

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**(12): 1100-1114.

Breber P 1997. The ideal salinity regime in Mediterranean lagoons. In: Özhan, E. (ed.), 1997. Proc. *3rd Interntl. Conf. Mediterranean Coastal Environment, MEDCOAST '97*. Vol. I: 91-96.

Breber P, Cilenti L, Pagliani T, Savino B, Spada A, Strada R, Scirocco T 2001. La valutazione della qualità ambientale delle lagune. *Biologi Italiani* **31**(6): 42-46.

Breber P, Scirocco T, Cilenti L 2000. An assessment of the fishery potential of Lesina lagoon (S. Italy) based on the composition and zonation of the macrobenthic fauna. *Periodicum Biologorum*, 102, Suppl. 1: 553-556.

Breber P, Strada R 1995. The abundance in an extensive brackish-water fish farm ("valle da pesca") of the animal macrobenthos that feeds the seabream (*Sparus* aurata). *Rivista Italiana Acquacoltura* 30: 181-186.

Brey T 1990. Estimating productivity of macrobenthic invertebrates from biomass and mean individual weight. *Meeresforschung* 32: 329-343.

Cuff W, Coleman N 1979. Optimal survey design: lessons from a stratified random sample of macrobenthos. *Journal of the Fisheries Research Board of Canada* **36**(4): 351 - 361.

Eaton L 2001. Development and validation of biocriteria using benthic macroinvertebrates for North Carolina estuarine waters. *Marine Pollution Bulletin*, **40**(1): 23-30.

Engle VD, Summers JK, Gaston GR 1994. A benthic index of environmental condition of Gulf of Mexico estuaries. *Estuaries* **17**(2): 372-384.

Frisoni G, Guelorget O, Perthuisot JP 1984. Diagnose écologique appliquée à la mise en valeur biologique des lagunes côtières Méditeranéennnes: approche méthodologique, in Kapetsky JM, Lasserre G (Eds), Management of Coastal Lagoon Fisheries, General Fisheries Council for the Mediterranean, Studies and Reviews 61, Food and Agriculture Organisation of the United Nations, Rome, 39-95.

Grall J, Glémarec M 1997. Using biotic indices to estimate macrobenthic community perturbations in the Bay of Brest. *Estuarine, Coastal and Shelf Science* **44**(A): 43-53.

Pearson TH, Rosenberg R 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Review* **16**: 229-311.

Perès JM, Picard J 1964. Nouveau Manuel de Bionomie Bénthique de la Mer Méditerranée. *Réceuil des Travaux de la Station Marine d'Endoume* **31**(47): 56-57.

Vatova A 1951. Le valli salse da pesca del Polesine, Parte I, Ricerche biologiche. *Nova Thalassia* **1**(10): 3-83.

Vatova A 1953. Un triennio di ricerche sulle valli salse da pesca. *Nova Thalassia* **2**(2): 3-17.

Weisberg SB, Ananda Ranasinghe J, Dauer DM, Schaffner LC, Diaz RJ, Frithsen JB 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries* **20**(1): 149-158.

