Norwegian Financial Mechanism and Republic of Lithuania

Coastal Research and Planning Institute, Klaipėda University

Project: A system for the sustainable management of Lithuanian marine resources using novel surveillance, modeling tools and ecosystem approach

## Technical Report No. 4

# ASSESSMENT OF BENTHIC QUALITY STATUS IN THE LITHUANIAN COASTAL WATERS BASED ON THE BENTHIC QUALITY INDEX (BQI)

Project indicator:
1. Documented assessment of fish feeding ground quality

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## INTRODUCTION

Benthic quality index (BQI) was developed and introduced by Rosenberg et al. (2004) and during recent years became one of the most applied indices for the assessment of benthic quality status. Its use in the Baltic Sea region was boosted by implementation of the Water Framework Directive. The development of BQI index so far was mainly based on the data from the western Baltic, therefore its application for different environments was difficult due to limitations of species sensitivity values.

Aim of this study was to develop sensitivity classification of the south-eastern Baltic macrofauna and apply BQI for the quality assessment of Lithuanian coastal area using newly derived thresholds of ecological quality classes.

## 1. MATERIALS AND METHODS

### 1.1 Study area and field data

#### 1.1.1 Development of benthic quality index

For the development of BQI a long-term dataset of 47 sampling events with 94 records of benthic macrofauna samples from the 5 monitoring sites (Figure 1) within the Lithuanian coastal zone soft-bottom habitats were analysed. All the samples were gathered during 1982-2009 years, using Van Veen grab with 0.1 $m^2$ sampling area, and analysed following standard guidelines for bottom macrofauna sampling (HELCOM 1988). Replicate samples were averaged for abundance and species number.

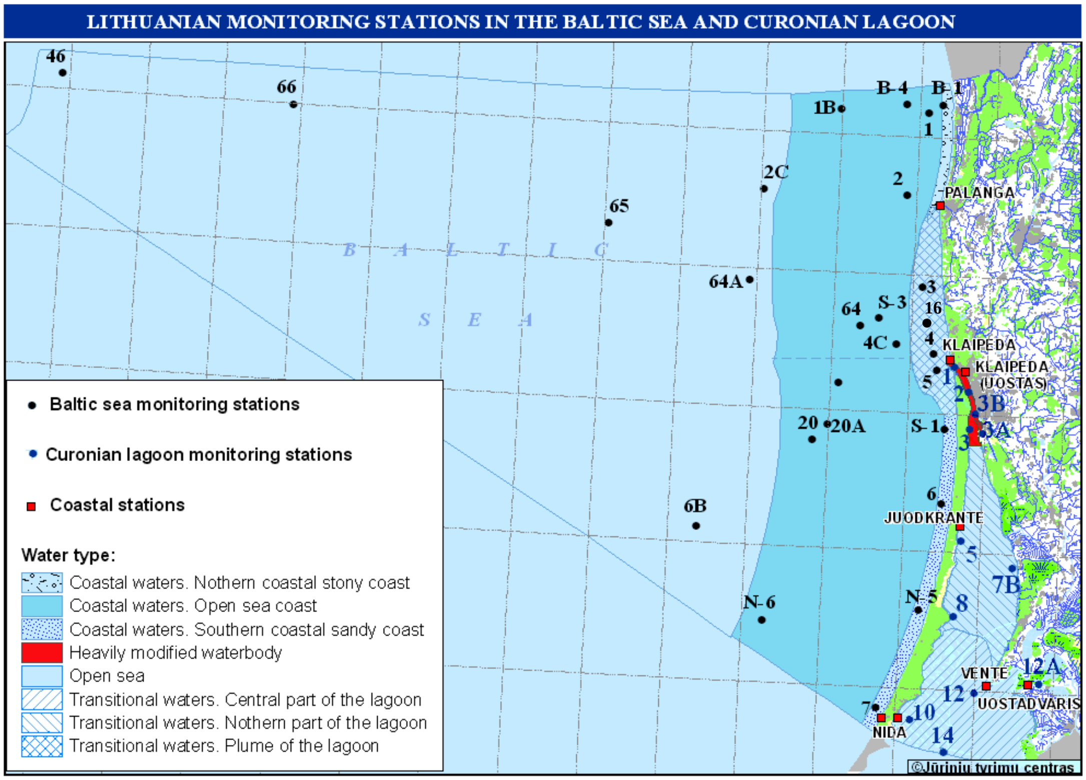


*Figure 1. Lithuanian monitoring stations in the Baltic Sea and Curonian Lagoon. Benthic macrofauna data for the development of BQI index were taken at stations 4, 5, 6, 7 and 16.*

#### 1.1.2 Assessment of benthic quality status

The assessment of benthic quality status was carried out for 87 soft-bottom sites in depths of less than 20 m. Samples were gathered during 2002-2010. Van Veen grab with 0.1 $m^2$ sampling area were used for areas deeper than 4 meters, while for the shallow ones a cylinder with 0.008 $m^2$ sampling area were used by the SCUBA divers. Samples were analysed following standard guidelines for bottom macrofauna sampling (HELCOM 1988). Replicate samples were averaged for abundance and species number.

For the assessment of temporal changes in BQI values five monitoring sites were selected: BT1, BT2, J5, J6 and J7 from depths of 12.0, 17.4, 20.3, 17.1 and 16.2 respectively (Figure 6).

### 1.1.3 Plume area

Plume area (Figure 1) was defined as low salinity area where annual average salinity is less than 6 PSU and which is formed by the fresh water outflow from the Curonian lagoon. Aside from lower salinity plume waters are characterised as more turbid and with high loads of nutrients due to hypereutrophic conditions in the lagoon.

## 1.2 Application of benthic quality index for the assessment of benthic quality status in the Lithuanian coastal waters

### 1.2.1 Application of benthic quality index

For the assessment of benthic quality a Benthic Quality Index (BQI) proposed by Rosenberg et al. (2004) was applied. Since the original version of BQI is known to be sampling effort dependent (Fleischer et al. 2007; Fleischer, Zettler 2009), and sampling effort of the existing data was heterogeneous in terms of replication, the adjusted calculation was applied (Fleischer, Zettler 2009):

$$BQI_{ES} = \left( \sum_{i=1}^{n} \left( \frac{A_i}{A_{tot}} \cdot ES50_{0.05i} \right) \right) \cdot \log(ES50 + 1) \cdot \left( 1 - \frac{5}{5 + A_{tot}} \right) \quad (1)$$

where n - the observed species number; Ai - stands for the abundance of the species *I*; Atot - the sum of all individuals within a square meter; $ES50_{0.05}$ - the sensitivity/tolerance value for species *i*; ES50 - estimated number of species for 50 individuals in a square meter.

The Primer 6 software package (Clarke and Warwick 1994) was used for calculation of the Hurlbert Index (ES50). As it was suggested by Rosenberg (Rosenberg et al. 2004), in order to exclude species occurring in a few samples only, the number of sample occasions where a species must be recorded should be limited to ≥ 20. ES50 is further estimated based on the numbers and total numbers of individuals of these pre-selected species with the following calculation of sensitivity values for these species.

### 1.2.2 Definition of tolerance values for benthic invertebrates

As described by Rosenberg et al. (2004) tolerant species are by definition predominantly found in disturbed environments. This means such species occurring at stations with low ES50. In contrast, sensitive species occur in areas with no or minor disturbance and hence would be associated with high ES50. The tolerance value of a species ($ES50_{0.05}$) was set to the 5th percentile of abundance distribution in relation to the lowest ES50. Tolerance values were calculated for 15 macrofauna species or higher taxa (Table 1).

*Table 1. Tolerance values for macrofauna species. Lower values denote tolerant species, higher – sensitive species.*

| Macrofauna species | Tolerance value $ES50_{0.05}$ |
|---|---|
| *Pygospio elegans* | 2.8 |
| *Macoma balthica* | 3.4 |
| *Saduria entomon* | 3.4 |
| Oligochaeta undet. | 3.4 |
| *Harmotoe sarsi* | 3.5 |
| *Marenzelleria neglecta* | 4.1 |
| *Corophium volutator* | 4.3 |
| *Hediste diversicolor* | 4.3 |
| *Hydrobia spp.* | 4.4 |
| *Mya arenaria* | 4.4 |
| *Bathiporeia pilosa* | 4.5 |
| *Cardium glaucum* | 4.8 |
| *Halicryptus spinulosus* | 5.1 |
| Nemertini undet. | 5.6 |
| *Streblospio shrubsoli* | 5.8 |

### 1.2.3 Definition of benthic quality classes

In order to determine the different sensitivity classes for macrofauna species following thresholds were set:

| | |
|---|---|
| very tolerant species | $ES50_{0.05} < 3$ |
| tolerant species | $3 \leq ES50_{0.05} < 4$ |
| sensitive species | $4 \leq ES50_{0.05} < 5$ |
| very sensitive species | $ES50_{0.05} \geq 5$ |

In order to set benthic quality thresholds, the distribution of relative abundance of each defined sensitivity class along the BQI gradient was plotted (Figure 2).

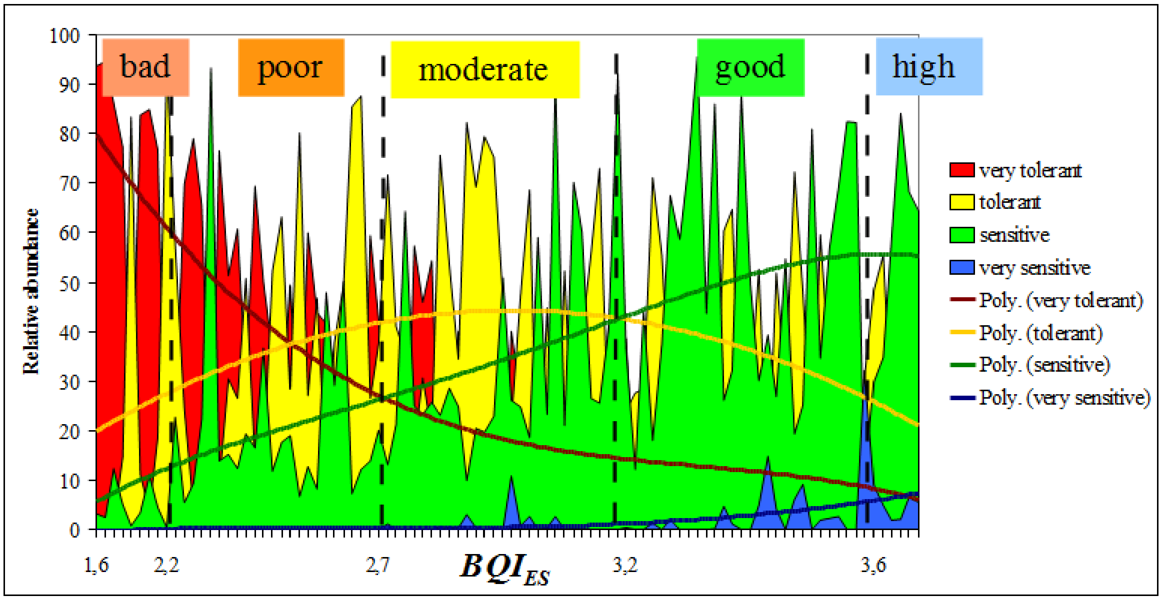


*Figure 2. Classification of soft-bottom macrofauna species into sensitivity classes according to the distribution of relative abundance along the BQI gradient. The dashed lines define boundaries among 5 benthic quality classes: bad, poor, moderate, good and high.*

Boundaries for benthic quality classes were set as described below (Table 2):

- *Bad status* (BQI<2.2) – benthic community is dominated (>60%) by very tolerant (opportunistic species), tolerant species are present, but comprise about 20% of the total species number. Sensitive and very sensitive species may occasionally appear at minor densities.
- *Poor status* (2.2<BQI<2.7) – very tolerant and tolerant species are present at about 40% relative abundance on average; sensitive species comprise >20%, very sensitive species may occasionally appear at minor densities. Upper threshold of this class was set to BQI value indicating prevailing relative abundance of sensitive species over very tolerant species.
- *Moderate status* (2.7<BQI<3.15) – tolerant species dominate the benthic macrofauna community in most of samples and average abundance of sensitive species prevails over that of very tolerant species. Very sensitive species appear at low abundances but in more than half of samples, while tolerant species are reaching the highest relative abundance values. Upper class boundary was set to BQI value, which distinguish dominance of sensitive species over tolerant species in terms of their relative abundance.
- *Good status* (3.15<BQI<3.6) – benthic macrofauna community is dominated by sensitive species. Average relative abundances of very tolerant species do not exceed 15% of the total macrofauna abundance. Boundary between good and high status (BQI=3.6) was set at peak of sensitive species abundance.
- *High status* (BQI>3.6) –sensitive species are always present. Abundance of very tolerant and tolerant species is low, whereas abundance of sensitive species starts to decrease at the costs of increasing numbers of very sensitive species.

*Table 2. Boundaries of benthic quality classes according to BQI values together with main quality class indicators.*

| | | | **Indicators** | | | |
|---|---|---|---|---|---|---|
| | | BQI | very tolerant species | tolerant species | sensitive species | very sensitive species |
| **Ecological quality class** | bad | <2.2 | >60% of total abundance | | | |
| | poor | 2.2-2.7 | <60% of total abundance | significant increase | significant increase | |
| | moderate | 2.7-3.15 | less than sensitive species | highest abundance | more than very tolerant species | |
| | good | 3.15-3.6 | | less than sensitive species | more than tolerant species | occur in more than 50% of sites |
| | high | >3.6 | | | decrease at the cost of increase of very sensitive species | occur in all sites |

### 1.3 Relations of BQI index to winter nutrient levels

No apparent eutrophication gradient exist in the Lithuanian coastal waters except along the increasing distance from the Curonian lagoon outflow. The later should assume lower eutrophication pressure and hence higher benthic quality at the same water depth. For the assessment of relations of BQI index to winter nutrient levels BQI values were plotted against the annual winter concentrations of nitrates (Figure 3) in four monitoring sites: 4, 5, 6 and 7 during years 1982-2009 (Figure 1). No significant relations were recorded except in station 7, however all the relationships showed negative values and regression slope increased towards the south with increasing distance from the Curonian lagoon. These results show that BQI better reflects dynamics of winter nitrogen concentrations outside the plume area, where effects of the eutrophied Curonian lagoon waters are not mixed with salinity impacts. This demonstrates the need to introduce salinity correction for the assessment of benthic quality according to BQI index.

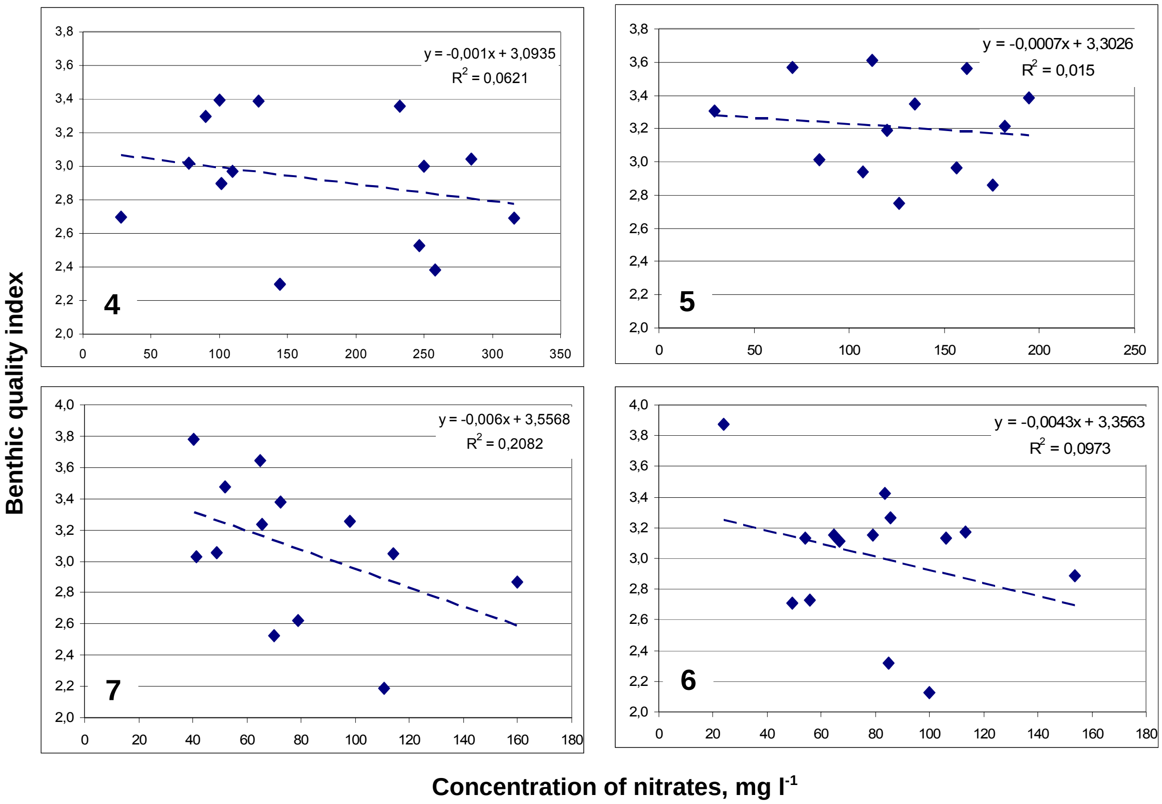


*Figure 3. Relations between BQI values and winter concentration of nitrates. Numbers in the bottom left corner indicate monitoring site (increasing southward direction).*

## 2. RESULTS AND DISCUSION

During the period of 2002-2010 in 87 sites *poor* benthic quality status was recorded most often (figures 4 and 6) and comprised more than 30%. *Bad* and *moderate* status were determined at more than 20% of sites, while *good* and *high* quality status were observed only at 6% and 4% of sites respectively.

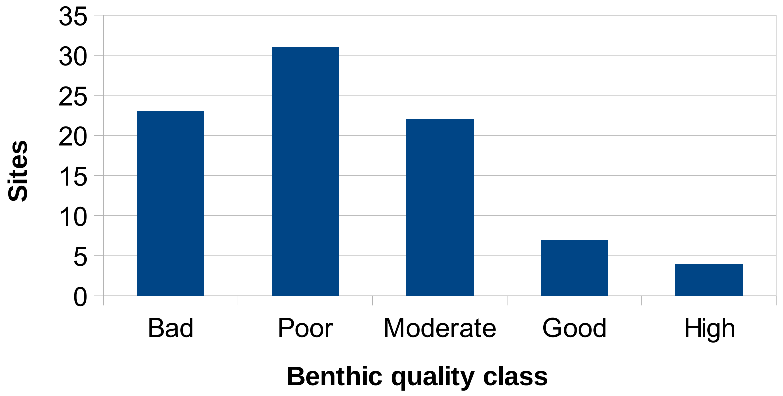


*Figure 4. Benthic quality class records at 87 research sites during years 2002-2010.*

2.1 BQI values along the depth and salinity gradients

Although of a limited depth range included in the study, BQI values demonstrated depth dependency: *high* quality status was observed only near the 20 meter margin while shallow areas mostly ranged from *bad* to *moderate* status. The regression analysis (Figure 5) showed that there is a significant but weak relationship between depth and BQI (r=0.37, p<0.001).

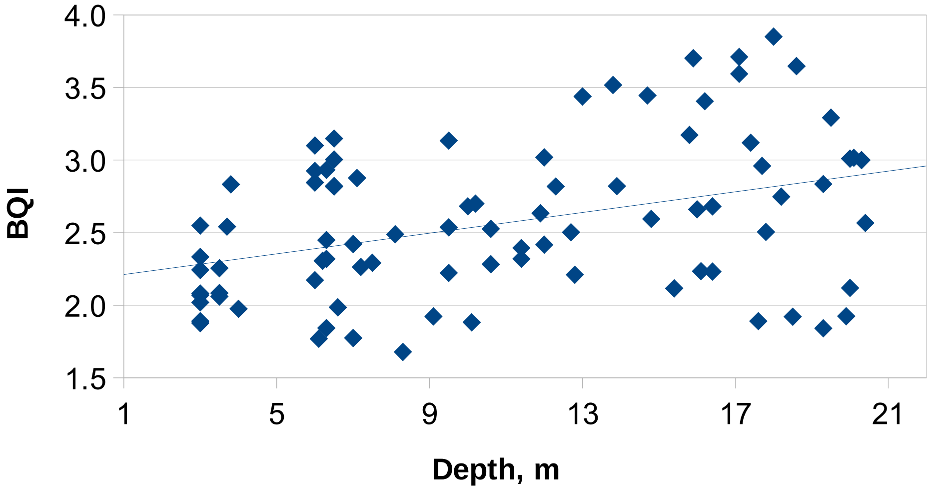


*Figure 5. Relationship between depth and BQI values (r=0.37, p<0.001).*

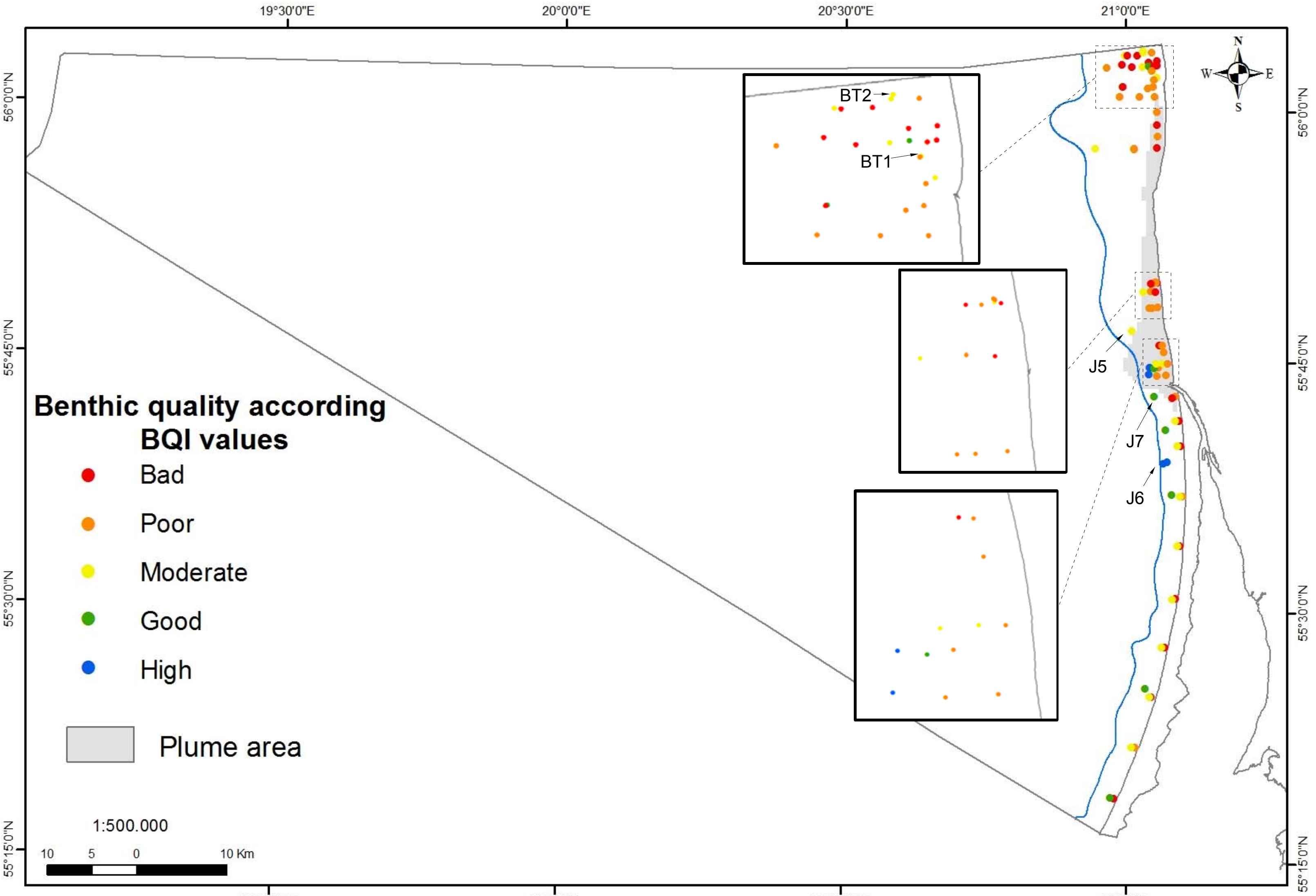


*Figure 6. Benthic quality according to BQI at 87 sites in the Lithuanian coastal waters during 2002-2010. Grey color indicates plume area, where annual average salinity is less than 6 PSU*

Very strong significant correlation between depth and wave exposure, (r=−0.82, p<0.001) demonstrate, that the most shallow areas are extremely affected by wave exposure and only few soft-bottom macrofauna species (e.g. *Marenzelleria neglecta* and *Bathyporeia pilosa*) can survive in these conditions. Since BQI index depends on species diversity, exposed shallow stations typically have lower quality status in comparison to deeper sites, though it does not necessarily mean bad quality of the seafloor.

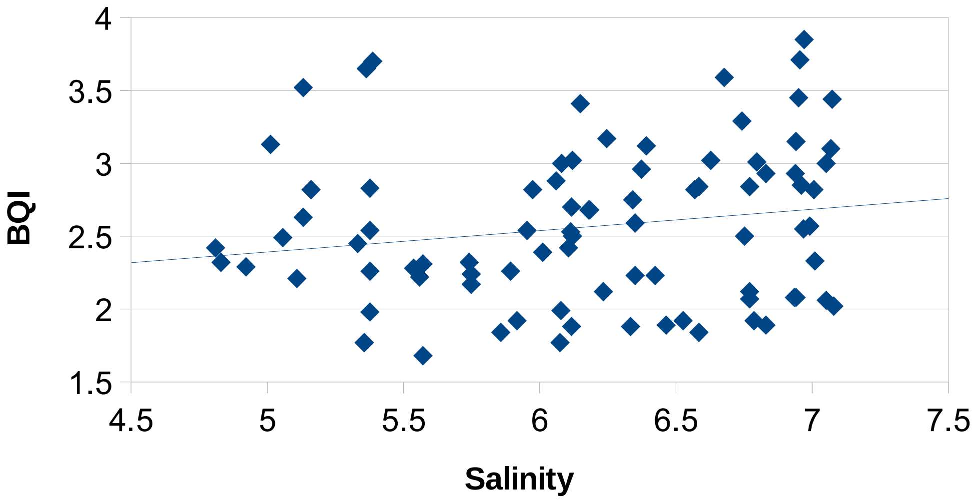
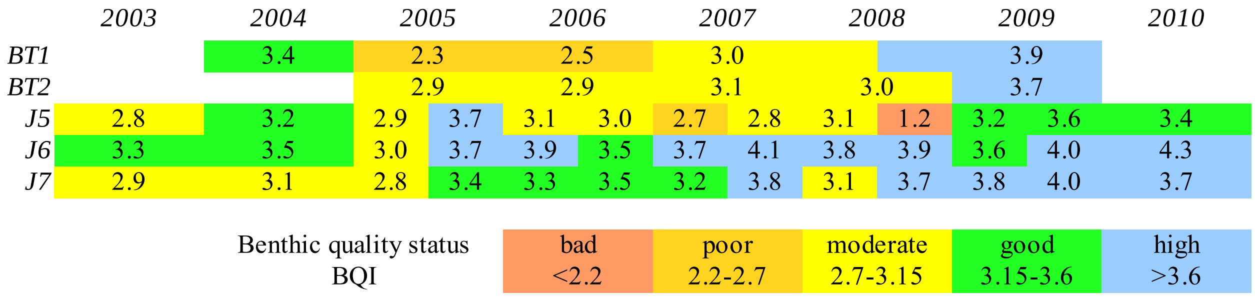


*Figure 7. Relation between salinity and BQI values; r=0.18, p>0.05.*

2.2 Temporary changes in BQI values

Eight year monitoring was performed at several research sites in the northern (BT1, BT2) and central part (J5, J6, J7) of the Lithuanian coastal waters. During these years a tendency of increase in benthic quality was recorded (Figure 8). During that period all quality status classes were observed, however a single record of *bad* status (J5 site in 2008) occurred probably due sampling errors, thus should be interpreted very carefully (it was not included in further analysis).



| | *2003* | *2004* | *2005* | *2006* | *2007* | *2008* | *2009* | *2010* |
|---|---|---|---|---|---|---|---|---|
| *BT1* | | 3.4 | 2.3 | 2.5 | 3.0 | | 3.9 | |
| *BT2* | | | 2.9 | 2.9 | 3.1 | 3.0 | 3.7 | |
| *J5* | 2.8 | 3.2 | 2.9 3.7 | 3.1 3.0 | 2.7 2.8 | 3.1 1.2 | 3.2 3.6 | 3.4 |
| *J6* | 3.3 | 3.5 | 3.0 3.7 | 3.9 3.5 | 3.7 4.1 | 3.8 3.9 | 3.6 4.0 | 4.3 |
| *J7* | 2.9 | 3.1 | 2.8 3.4 | 3.3 3.5 | 3.2 3.8 | 3.1 3.7 | 3.8 4.0 | 3.7 |

| Benthic quality status | bad | poor | moderate | good | high |
|---|---|---|---|---|---|
| BQI | <2.2 | 2.2-2.7 | 2.7-3.15 | 3.15-3.6 | >3.6 |

*Figure 8. Temporal changes in benthic quality status according to BQI values. In the top part of the figure – BQI values of sampling events, in the bottom – colour and BQI range of benthic quality status.*

*Moderate* and *good* benthic quality status was recorded in 2003 and 2004 in all research sites. In 2005 and 2006 benthic quality became worse (*poor-moderate* status) in BT sites, while in the central part quality got better (*moderate-high* status). From 2007 BQI values started to rise and in 2009 and 2010 *good-high* benthic quality status was reached at all sites. Increase in benthic quality was higher in sites outside the plume area (BT1, BT2, J6, J7) in comparison to station J5.

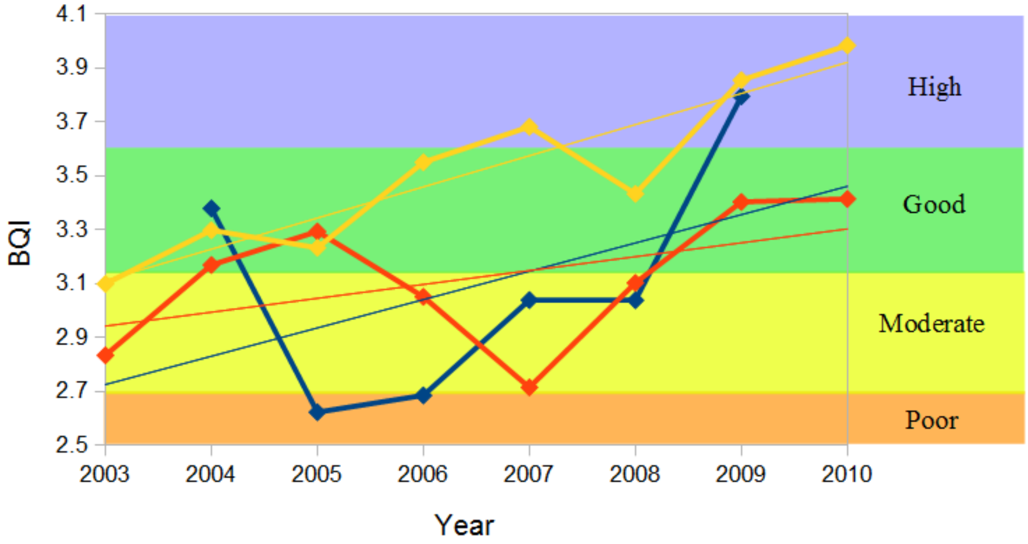


*Figure 9. Temporal changes in benthic quality status according to BQI in the northern (BT1, BT2 sites – blue line), central (J6, J7 sites – yellow line) parts of coastal area and in the plume area (J5 site – red line). Thin lines show linear regression. Station numbers according to Fig. 6.*

Long-term results for stations 4, 6 and 7 (Figure 1) show similar tendencies (Figure 10) where increase from *poor* status in 1984 to *good-high* status in 2009 were recorded outside the plume area, while the status in the plume area varied between *bad* and *good* with no signs of increase in benthic quality.

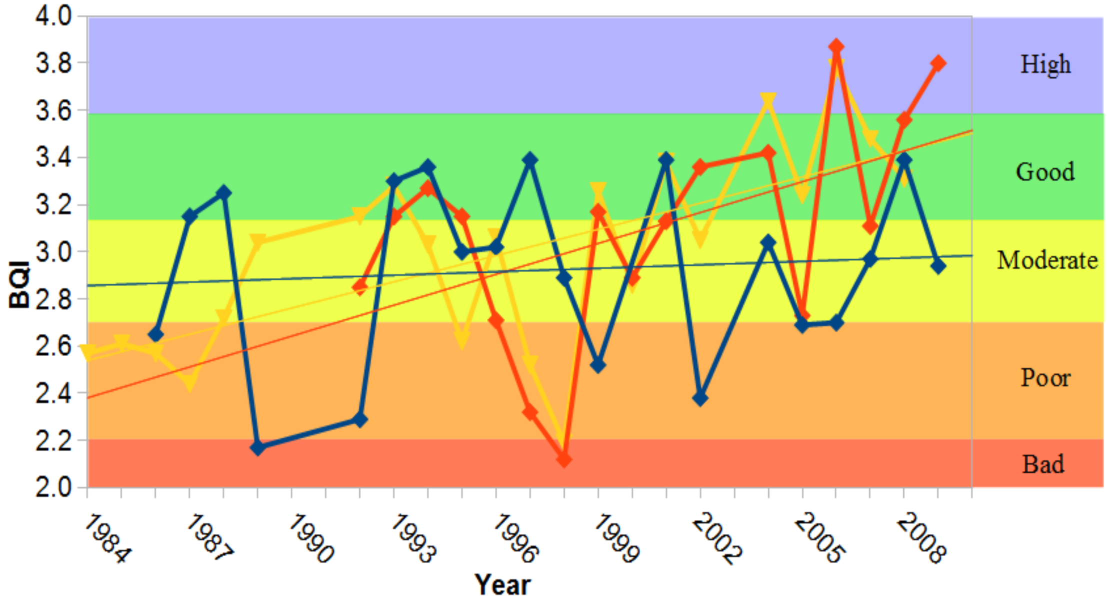


*Figure 10. Long-term changes in benthic quality status according to BQI in monitoring stations outside plume area (station 6 – red line and station 7 – yellow line) and in the plume area (station 4 – blue line). Thin lines show linear regression; station numbers according to Fig. 1.*

## CONCLUSIONS

Sensitivity values of 15 benthic macrofauna species were derived after analysis and used in the quality assessment. Threshold values of quality classes were determined according to the developed species sensitivity classification and BQI was applied for the Lithuanian coastal waters.

Increasing distance from the Curonian lagoon outflow was used as the only available eutrophication gradient for index testing. Negative correlation between BQI index and the annual winter concentrations of nitrates was found for all sites along the gradient, and regression slope increased with decreasing distance. These results show that BQI reflects dynamics of winter nitrogen concentrations outside the plume area, where effects of the eutrophied Curonian lagoon waters are not mixed with salinity impacts.

According to BQI values the benthic quality tends to increase over the last 28 years (from *poor-moderate* to *good-high* status) outside the plume of the Curonian lagoon, however this is valid for soft-bottom areas deeper than 10 m. In shallow areas which are naturally devoid of many benthic species good status was recorded only once, while *bad-moderate* status occurred most often. Since BQI index reflects impacts of natural environmental parameters (e.g. wave exposure or mobility of substrate), it should not be used for quality assessments of the seafloor in low depths and should be corrected for salinity effects for applications in the plume area.

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