BENTHIC ECOSYSTEM QUALITY INDEX 2:
CALIBRATION OF THE BEQI-2 WFD METRIC FOR
MARINE BENTHOS IN COASTAL WATERS

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This report will be published in the near future in an international journal. Therefore, please use this report for the purpose of intercalibration only.

<table>
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<tr>
<td>Acknowledgements</td>
<td>Angel Borja, Peter Bot, Gert van Hoeij, Marcel van de Berg, Joao Neto, Hans Ruiter and Maria Dulce Subida are acknowledged for their valuable information and comments.</td>
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<td>Legend front page figure</td>
<td>View on gullies between the Wadden islands Texel and Vlieland.</td>
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**SUMMARY**

The BEQI-2 for coastal waters is a next implementation of the BEQI-2 developed for transitional waters (see Van Loon et al., 2011). The summary of this report is given as a method summary fact sheet. For more technical details see the TW report.

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<tr>
<td>Calibration method</td>
<td>The BEQI-2 is calibrated by straightforward univariate calibration of the three individual indicators. The resulting BEQI-2 EQR values are very similar to the corresponding m-AMBI EQR scores. However, the BEQI-2 univariate calibration procedure is transparent and the resulting indicator-EQR values can be communicated well to policy makers and water managers. In addition, the BEQI-2 EQR values calculations can be automated relatively easily compared with the m-AMBI. Very good correlations between BEQI-2 and m-AMBI EQRs have been demonstrated for the Westerschelde and NEAGIG common dataset.</td>
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<table>
<thead>
<tr>
<th>Water types</th>
<th>Open coastal water: NEA type 1, Dutch type K1 and K3. Sheltered coastal water: NEA type 3/4, Dutch type K2 (Wadden sea)</th>
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<tr>
<td>Ecotope classification</td>
<td>The NEAGIG ecotope classification is used: NEA1 (coastal water; poly- and euhaline combined), NEA3/4 (Polyhaline-Intertidal and Polyhaline-Subtidal).</td>
</tr>
<tr>
<td>Season</td>
<td>In coastal waters only spring data are available. In the Wadden Sea both spring and autumn data are available. If available, the autumn benthos data are preferably used for the WFD assessment.</td>
</tr>
<tr>
<td>Data period</td>
<td>1991 - 2006</td>
</tr>
<tr>
<td>Sample area and data pooling</td>
<td>For the coastal area, the box core samples (0.068 and 0.078 m²) were analyzed directly. We will standardize the sample area of the box core samples to 0.1 m² in the national BEQI-2 software in 2012. The Wadden Sea samples were randomly pooled to 0.1 m² ± 0.02 m².</td>
</tr>
<tr>
<td>Reference and Bad values</td>
<td>Reference values: S(ref) = 99p, H(ref) = 99p, AMBI(ref) = 0. Bad values: S(bad) = 0, H(bad) = 0, AMBI(bad) = 6.</td>
</tr>
<tr>
<td>Trends and Pressure-Impact relationships</td>
<td>Especially in the Wadden Sea, several significant trends were found for Species richness, Shannon and BEQI-2. In the three coastal zones, significant negative trends were found for Species richness. These trends can probably be explained by the strong increase of the several non-native Ensis species. At this moment, it was not yet attempted to find quantitative pressure-impact relationships for BEQI-2 in coastal waters, since at present we have a lack of good quantitative physical human pressure data in the coastal zone. However, for the Marine Strategy and large marine RWS projects these pressure studies are in progress in the Netherlands. However, it is very likely that the demonstrated human pressure sensitivity of BEQI-2 in transitional waters will also hold in coastal waters.</td>
</tr>
<tr>
<td>Validation of BEQI-2 with expert judgement</td>
<td>Based on expert judgement for the Westerschelde, the Wadden Sea and the Dollard, it appears that a Good/Moderate boundary of 0.58 (national scale) gives realistic classification results. In view of the standard Dutch class boundaries of 1, 0.8 (High/Good), 0.6 (Good/Moderate) etc., we will apply a national linear transformation</td>
</tr>
</tbody>
</table>
on both the BEQI-2 EQR values and the class borders. This transformation will not change the intercalibrated classification results of BEQI-2. For possible EU comparisons untransformed national BEQI-2 EQR values will be used.

Comparison of BEQI-2 with m-AMBI

It has been demonstrated for coastal and transitional waters, that if the sample surface is sufficiently large (>0.065 m²) and the reference values are the same, a very good correlation (R²-range 0.97-0.99; systematic difference <2%) between the BEQI-2 and m-AMBI is observed at the sample level. The results show that BEQI-2 practically gives the same EQR scores as m-AMBI.

Intercalibration

For NEA1, intercalibration calculations have been performed according to the Annex V procedure and using the Birk IC spreadsheet (see Van Loon, 2011). The results of these calculations have been described in a Milestone 6 report and sent to Angel Borja, the NEAGIG and the EU Joint Research Centre. For NEA3/4 (Dutch and German Wadden Sea), IC of the Dutch and German class boundaries could not be achieved at this moment within the Annex V class boundary criteria. Therefore, no IC results were submitted for NEA3/4 yet.

List of Definitions and Abbreviations

<table>
<thead>
<tr>
<th>Subject</th>
<th>Full description / Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMBI</td>
<td>AZTI Marine Biotic Index. A well-known benthic species quality indicator.</td>
</tr>
<tr>
<td>BEQI-2</td>
<td>Benthic Ecosystem Quality Index 2. The Dutch WFD metric for marine benthos. The BEQI-2 is an improved version of the BEQI-1.</td>
</tr>
<tr>
<td>CW</td>
<td>Coastal water</td>
</tr>
<tr>
<td>H'</td>
<td>Shannon index. A very commonly used ecological diversity indicator. This index assesses a combination of the Species richness and relative abundances of species. Note: this index can have a log base 2, e or 10. In the BEQI-2 and m-AMBI, log base 2 is used.</td>
</tr>
<tr>
<td>IC</td>
<td>Intercalibration</td>
</tr>
<tr>
<td>ITI</td>
<td>Infaunal trophic index. This index is based on the classification of species into four trophic groups.</td>
</tr>
<tr>
<td>Macrozoobenthos</td>
<td>Animals which live in (endofauna) or on top of (epifauna) the soft bottom sediment that are retained at a sieve with a mesh size of 1 mm. Epifauna may be sessile or mobile. Hard bottom benthos is not included in the WFD definition.</td>
</tr>
<tr>
<td>m-AMBI</td>
<td>Multivariatie AMBI. Factorial and discriminant analysis using the indicators AMBI, S and H' and multivariate calibration.</td>
</tr>
<tr>
<td>S</td>
<td>Species richness. A very commonly used ecological diversity indicator.</td>
</tr>
<tr>
<td>TW</td>
<td>Transitional water</td>
</tr>
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1. Introduction

The design and calibration of BEQI-2 for transitional water has been described recently (Van Loon et al., 2011). In this report, the BEQI-2 the calibration results for BEQI-2 in coastal waters are described. By using the BEQI-2 in both coastal and transitional waters, a very good comparison is obtained at a national scale (by using one uniform national method) as well as in Western Europe (very good comparability with among others the m-AMBI and BAT).

The BEQI-2 is composed of two parts: (a) a benthos quality assessment and (b) a benthos area assessment. It is important to note that only the BEQI-2 benthos quality assessment is intercalibrated, because other NEAGIG member states do not perform a benthos area assessment. For this reason, The Netherlands will not report the assessment of area in their WFD reports.

The structure of this report is identical to the BEQI-2 Transtional Water report. However, for more information on methodological aspects is referred to the TW report.

This technical report describes the calibration of the BEQI-2 for coastal waters. For the intercalibration procedure and results, see the BEQI-2 Milestone 6 report for Coastal waters and the associated Birk workbook (Van Loon, 2011).

2. Selection of datasets

Benthos data
We received the IC Phase 1 benthos dataset for NEA1, NEAGIG Benthic-All Samples.xls, from Angel Borja. We used the German, Spanish and Dutch samples from this dataset in order to get an essential picture of the comparability in the North East Atlantic region.

The MacBEQI(ii) database containing only the official Dutch RWS MWTL marine benthos monitoring data were used for the calibration calculations.

For the Wadden Sea station data we used the file “macWZ_1989-2007.xls” (part of the RWS MWTL data, but benthos abundance data available at the station level instead of the transect level). Approx. 2000 samples are available for this period.

Results BEQI-2 EQR results for the phase 1 samples from Netherlands, Germany and Spain are given in the file “EQRs BEQI-2 phase 1 data NL DE ES 6 okt 2011.xls”. EQR results from phase 1 were received from Angel Borja and are stored in the file “5 EQR intercalibrado.xls”.

3. Ecotope Classification, Sample Availability and Quality Control

3.1 Ecotope classification
The distinction of ecotopes is an important method in the benthos assessment in order to improve the comparability of benthos data and to reduce the natural variability. If a suitable ecotope classification is used, the possibilities for trend analysis within an ecotope, and the comparison of similar ecotopes from different West European countries, improves significantly.

In the Dutch open coastal zone (type NEA1) MWTL benthos data, a deep_polyhaline zone and a deep_euhaline and shallow_euhaline zone are distinguished. However, for the intercalibration of NEA1 this discrimination has not been made in the past. Therefore, the Dutch samples from these three ecotopes have been combined into 1 Dutch coastal data set type NEA1. However, for the Dutch WFD assessments we will divide the coastal data over five national water bodies in the coastal zone (Zeeuwse Kust, Noordelijke Deltakust, Hollandse Kust, Waddenzee, Eems Dollard kust). In this report, we have first tested the
BEQI-2 with a division of the benthos data over three major zones, namely the Voordelta, the Hollandse Kust and the Waddenkust.

In this type Wadden Sea type (NEA3/4), we distinguish two NEAGIG standardized ecotopes: Polyhaline-Intertidal and Polyhaline-Subtidal. We share this type with Germany. We have simplified our national ecotope classification for this NEAGIG comparability.

3.2 Sample availability
In the intercalibration sample data set from phase 1, approx. 180 samples are available for The Netherlands (60 samples), Germany (64 samples), Spain (45 samples) and Portugal (12 samples).

For the Dutch coastal waters, for the period 1991-2006, 219 box cores samples are available which have been sampled in the coastal regions Voordelta (Zeeuwse kust and Noordelijke Deltakust; N = 63), Hollandse Kust (N = 76), Waddenkust (N = 64) and Eems Dollard kust (N = 16). Note that these samples have always been taken in spring. From 1991 until 1998, box core samples of 0.068 m² were taken. In 1999, the box core size was changed to 0.078 m². We will standardize the coastal sample areas to 0.1 m² in 2012 in the national BEQI-2 software, using suitable Species and Shannon accumulation curves. This could lead to very small changes of BEQI-2 EQR values and trends, but is not expected to give a different picture.

3.3 Quality control
We tested the coastal box core data using the m-AMBI criteria (Species richness > 3; Total abundance > 6; percentage of total abundance AMBI classified > 80%; Borja & Mader, 2006). It appeared that practically all samples meet these criteria.

For the Wadden Sea samples, we used data pooling to get a standardized surface area of 0.1 m².

The BEQI-2 script reports per sample or data pool of 0.1 m²: (a) the number of taxa, (b) the total abundance and (c) per indicator which percentage of the abundance is not AMBI-classified.

The BEQI-2 script uses a list of standardized taxa from the NEAGIG, and a separate list of taxa synonyms and their standardized taxa names.

4. Data pooling
For the Wadden Sea manual core samples, data pooling was used to obtain data pooles of 0.1 ± 0.02 m².

For the coastal water box core samples pooling was not necessary. We will standardize the coastal sample areas to 0.1 m² in 2012, using suitable Species and Shannon accumulation curves. This could lead to slight improvements in the significance of BEQI-2 trends.
5. BEQI-2 Design and Trends in Coastal Waters

5.1 BEQI-2 Design in Coastal Water

The identical BEQI-2 metric as for coastal waters is used in transition waters. This offers the following advantages:

a. The BEQI-2 scores for coastal waters and transitional waters can be compared directly at the national level which is very useful.

b. The very good comparability of BEQI-2 with m-AMBI is maintained, resulting in a good intercalibratability.

The univariate formula used in BEQI-2 is:

\[
EQR\text{ (ecotope)} = \frac{1}{3} \left( \frac{S_{\text{ass}}}{S_{\text{ref}}} \right) + \frac{1}{3} \left( \frac{H'_{\text{ass}}}{H'_{\text{ref}}} \right) + \frac{1}{3} \left( \frac{(6 - \text{AMBI}_{\text{ass}})}{6} \right)
\]

There appear to be small but probably significant differences in the EQR-values obtained in spring and autumn, and therefore a choice has to be made which season to use for assessment. If available, autumn benthos data should be used for the WFD assessment, because BEQI-2 results show that more significant trends are found using autumn benthos data compared with spring data. This was also recommended in the BEQI-2 review (Boon et al., 2011), because the full grown benthos individuals can be identified and counted more easily than in spring (more small juveniles). In the Wadden Sea, Westerschelde (only autumn data) and Eems Dollard autumn benthos data are available. In the Coastal zone, only spring data are available.

According to expert judgement (see Table 5), a Good/Moderate and High/Good class boundary of 0.58 and 0.78, respectively, applied to untransformed national BEQI-2 EQR values, give realistic BEQI-2 classification results. However, in our national classification system we use equidistant class boundaries for all our Dutch WFD metrics (High/Good = 0.8, Good/Moderate = 0.6, Moderate/Poor = 0.4 and Poor/Bad = 0.2). Therefore, we will apply a linear transformation to our national class boundaries and national BEQI-2 EQR values, in order to be able to use these preferred equidistant class boundaries, as shown in Table 1 below. Since the national BEQI-2 EQR values will also be transformed, the BEQI-2 classification results will remain exactly the same as those intercalibrated.

Table 1: Intercalibrated, untransformed and transformed national BEQI-2 class boundaries.

<table>
<thead>
<tr>
<th>Class boundary</th>
<th>BEQI-2 IC PCM</th>
<th>BEQI-2 National Untransformed</th>
<th>BEQI-2 National Transformed</th>
</tr>
</thead>
<tbody>
<tr>
<td>High/Good</td>
<td>0.747</td>
<td>0.78</td>
<td>0.8</td>
</tr>
<tr>
<td>Good/Moderate</td>
<td>0.565</td>
<td>0.58</td>
<td>0.6</td>
</tr>
<tr>
<td>Moderate/Poor</td>
<td>Not defined</td>
<td>0.38</td>
<td>0.4</td>
</tr>
<tr>
<td>Poor/Bad</td>
<td>Not defined</td>
<td>0.18</td>
<td>0.2</td>
</tr>
</tbody>
</table>

For the WFD, in the end a water body assessment is necessary. All area within a water body must be represented and assessed by the ecotopes used. This will be achieved by combining the EQR-results of the different ecotopes in the water body using area based weight factors, which is a standard method in the Dutch WFD assessment protocol (Faber et al., 2010). The general formula for the combined WFD assessment of ecotopes is:

\[
EQR(\text{waterbody}) = \sum_i (EQR_i \times \text{Area fraction}_i)
\]

\(i\) is ecotope number
5.2 Indicator and BEQI-2 trends

Coastal zone
The Dutch coastal zone is composed of five WFD water bodies (from South to North): the Zeeuwse kust (coast), Noordelijke Deltakust, Hollandse kust, Waddenkust and Eems-Dollard kust. For this calibration report, the Zeeuwse Kust and Noordelijke Deltakust data, and the Waddenkust and Eems Dollard kust data, have been combined in order to obtain sufficiently large data sets for statistical analysis. However, these official water bodies will used for the national BEQI-2 assessments.

In the beginning of 2012 we will incorporate the BEQI-2 script in the standard Dutch WFD ecological assessment software. In this national software we will also incorporate the sample area standardization of the box core samples to 0.1 m².

It appears from the data in Figure 1, that in the three coastal regions no significant BEQI-2 trends are detected. However, a nearly significant slightly negative BEQI-2 trends is observed in the Waddenkust. The benthic quality in the Voordelta and Hollandse Kust appears to be stable.

When the BEQI-2 indicators are analyzed, it appears that significant negative trends for S are observed all three coastal areas. The values for R and p are very similar for these three regions. This remarkable decline of the number of species correlates well in time with the increase of the abundance of *Ensis directus* (see Figure 3). It has been reported before in the Netherlands that the introduction of *Ensis directus* in the Dutch coastal waters in the eighties has had an important impact on the benthic community structure (“regime shift”), leading to a biomass dominance of *Ensis directus* at present (Anonymous, 2008; Tulp et al., 2010). This *Ensis* dominance therefore seems a plausible explanation of the remarkable reduction of the number of species since the beginning of the nineties.

The Shannon index shows a significant positive trend in the Hollandse Kust (slope = 0.0379, R = 0.563, p = 0.023). In the other two regions no significant Shannon trend is observed.

The AMBI does not show significant trends in the three coastal regions. The AMBI review does not clearly give better results than the standard AMBI in the three coastal regions. Therefore, there appears to be no need to replace the standard AMBI with the AMBI review.

The AMBI fisheries and, to a lesser extent, the AMBI sedimentation, appears to give significant positive quality trends in the Hollandse kust and Voordelta (r ~ 0.7), but not in the Waddenkust. However, since in most water bodies the AMBI fisheries and sedimentation do not give plausible results, we cannot clearly recommend the AMBI fisheries and sedimentation for further testing.

The ITI shows a significant negative trend in the Hollandse Kust (slope = 0.102, R = 0.760, p = 0.00064). However, in the Voordelta and Waddenkust the significance of the ITI trends was very low. It is not clear why this is the case. Furthermore, the number of species in coastal waters without an ITI classification is quite high (58%). Therefore, we are not confident that the ITI values and trends are reliable in coastal waters. This is in contrast with the AMBI, for which practically all species are classified. Since the ITI only appears to give significant results in the Hollandse Kust, this does not give a clear recommendation for further investigation of the ITI.

In conclusion, the BEQI-2 results for the coastal zones show a more or less stable BEQI-2 score, but with a (nearly significant) negative trend in the Wadden Coast. Furthermore, the analysis of the indicator trends shows a remarkable decline of the Species richness, probably caused by the increase and dominance of *Ensis directus* (Anonymous, 2008; Tulp et al., 2010). This can be considered an important quality signal of the BEQI-2 at the indicator level.
Figure 1: BEQI-2 EQR-trends for three Dutch coastal zones

**Hollandse Kust**

The Hollandse Kust no significant BEQI-2 trend can be observed (p = 0.674). However, a significant negative trend for S has been found (see Figure 2).

R = 0.114  
P = 0.674

**Voordelta**

The trend analysis does not show a significant decreasing quality trend (p = 0.154). In the period 2000 to 2006 a stable BEQI-2 EQR can be observed, slightly above the proposed G/M border of 0.58.

R = 0.373  
P = 0.154

**Waddenkust**

The trend analysis shows a nearly significant negative quality trend (p = 0.083).

Further analysis of this possible trend shows that the Species richness shows a significant negative trend (p = 0.021), see Figure 2.

R = 0.447  
P = 0.083
Figure 2: Trends for Species richness in the three Dutch coastal regions

- **S in Hollandse Kust**
  - $R = 0.566$
  - $p = 0.022$

- **S in Waddenkust**
  - $R = 0.572$
  - $p = 0.021$

- **S in Voordelta**
  - $R = 0.563$
  - $p = 0.023$
**Waddenzee**

In the Polyhaline-Intertidal ecotope, small and non-significant decrease of the BEQI-2 EQR values is observed (See Figure 4). In the Polyhaline-Subtidal ecotope, a significant increase of BEQI-2 is observed in both spring and autumn (See Figure 4). Since the positive quality trend is stronger, the benthic quality in the Wadden Sea is slightly improving. However, it is recommended to investigate the non-significant BEQI-2 decrease in the Intertidal zone.

The indicator Species richness shows a significant negative trend (slope = -0.31, r = 0.68, p = 0.0028) in the ecotope Polyhaline-Intertidal-autumn.

The indicator Shannon shows a significant positive trend (slope = 0.0796, r = 0.72, p = 0.0074) in the ecotope Polyhaline-Subtidal-Autumn.

The indicator AMBI shows a nearly significant positive quality trend in the ecotope Polyhaline-Intertidal-Autumn (p = 0.008). The AMBI review does not give better significances than the standard AMBI.

In the Polyhaline-Subtidal-Autumn, the ITI shows a positive quality trend (p = 0.0075) which is consistent with the significant positive Shannon and BEQI-2 trends. In this same ecotope, the AMBI fisheries shows a significant negative quality trend (p = 0.01) which seems less plausible.

In conclusion, the BEQI-2 results for the Waddenzee show an overall slightly increasing BEQI-2 score, in which the Polyhaline-Subtidal shows a significant increasing quality and the Polyhaline-Intertidal a small but non-significant decreasing quality. It is recommended to investigate the causes for the non-significant BEQI-2 decrease in the Intertidal zone.
Figure 4: BEQI-2 EQR- and indicator trends for the Wadden Sea, ecotopes Polyhaline-Intertidal and Polyhaline–Subtidal, autumn data. The trends for spring are similar.

6. Calculation of national reference values

6.1 Reference setting method

a. Statistical method to estimate reference values

The basic assumption in the statistical reference setting procedure is that the highest indicator value within an ecotope-dataset - which is not an outlier - is a usable estimation of the average reference situation of the higher benthic quality in the historical past. The indicator distributions (Figures not shown) have been analyzed in detail and show that the 99 percentiles of S and H are clearly not outliers, and are statistically robust to use as reference values. For AMBI the theoretical reference value of 0 is used, because: (a) the AMBI scale is well determined theoretically, (b) in the Westerschelde and coastal waters AMBI(ref) = 0 is closely approximated by measured data (c) this method is robust. In the Eems Dollard the use of AMBI(ref) = 1 percentile gave erroneously high AMBI-EQR results.
b. Bad values
For S, H and AMBI theoretical bad values can be determined well. Clearly, S(bad) and H(bad) must be 0; in a really bad ecotope no species can survive. For the calculation of an AMBI bad at least 1 species must survive so the ecotope must not be completely bad. It was recently reported by Gittenberger & Van Loon (2011) that in the Dutch marine waters 3 common class V benthic species occur. This makes it theoretically possible to reach an AMBI of 6 in Dutch marine waters. Therefore, a theoretical AMBI(bad) of 6 is used.

6.2 Reference values
The reference setting methods described above result in the Dutch reference values listed Table 2 (open coastal waters) and Table 3 (Waddenzee). For the intercalibration of NEA1 and NEA3/4 see the BEQI-2 Milestone 6 report for CW and the corresponding Birk workbooks (Van Loon, 2011).

Table 2: Reference values for the three Dutch coastal zones, type NEA1 (open coastal waters).

<table>
<thead>
<tr>
<th>Coastal area (NEA1)</th>
<th>S ref</th>
<th>S bad</th>
<th>H ref</th>
<th>H bad</th>
<th>AMBI ref</th>
<th>AMBI bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 zones below combined</td>
<td>36.82</td>
<td>0</td>
<td>3.695</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Voordelta</td>
<td>41.18</td>
<td>0</td>
<td>3.609</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Hollandse Kust</td>
<td>32.50</td>
<td>0</td>
<td>3.786</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Waddenkust</td>
<td>32.21</td>
<td>0</td>
<td>3.541</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3: Reference values used by Netherlands for NEA3/4 (sheltered coastal waters; Waddenzee type). In the Wadden Sea monitoring is performed in spring and autumn, and different reference values for S and H are calculated.

<table>
<thead>
<tr>
<th>Ecotope</th>
<th>S ref</th>
<th>S bad</th>
<th>H ref</th>
<th>H bad</th>
<th>AMBI ref</th>
<th>AMBI bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyhaline-Intertidal, Spring</td>
<td>23.3</td>
<td>0</td>
<td>3.622</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Polyhaline-Intertidal, Autumn</td>
<td>27.7</td>
<td>0</td>
<td>3.756</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Polyhaline-Subtidal, Spring</td>
<td>19.0</td>
<td>0</td>
<td>3.307</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Polyhaline-Subtidal, Autumn</td>
<td>24.7</td>
<td>0</td>
<td>3.390</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

It is interesting to observe that the Ref(S) in the Voordelta is 41, in Hollandse Kust 33 and in Waddenkust 32. This difference seems comparable with the higher species richness of the Westerschelde as compared with the Wadden Sea. Several explanations of this phenomenon are possible, such differences in climate (temperature) between the Northern and Southern Dutch estuaries and small differences in stringentness in species identification by the different benthos laboratories in de Delta, North Sea and Wadden Sea. However, other factors may also play a role here.
7. Pressure-Impact analysis

7.1 Qualitative pressure-impact analysis

From the official Dutch WFD documents per water body, a qualitative table with pressures and their significance was extracted (Bommelé & Baretta-Bekker, 2009).

**Table 4: Significant pressures reported in the Dutch WFD water body documents in the regions Deltakust (DK), Hollandse Kust (HK), Waddenkust (WK) and Waddenzee (WZ).**

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Regions</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood defences</td>
<td>HK, DK</td>
<td>Mitigating measures are taken</td>
</tr>
<tr>
<td>Dredging</td>
<td>HK, DK</td>
<td>Deepening of shipping lanes</td>
</tr>
<tr>
<td>Land acclaim</td>
<td>HK, DK</td>
<td>Second Maasvlakte, increase of land area</td>
</tr>
<tr>
<td>Sand suppletion</td>
<td>HK, DK,(WK)</td>
<td>For safety and maintenance</td>
</tr>
<tr>
<td>Dumping of unpurified sludge in sea</td>
<td>HK</td>
<td>Investigations are ongoing</td>
</tr>
<tr>
<td>Exotic species</td>
<td>HK, DK, WK, WZ</td>
<td>Changes in species structures/foodweb</td>
</tr>
<tr>
<td>Climate change</td>
<td>HK, DK, WK</td>
<td></td>
</tr>
<tr>
<td>Mining of sand, clay, gravel</td>
<td>HK, DK, WK</td>
<td>Effects on benthos</td>
</tr>
<tr>
<td>Import of contaminants</td>
<td>HK, DK, WK</td>
<td>From other regions</td>
</tr>
<tr>
<td>Shipping</td>
<td>HK, DK, WK</td>
<td></td>
</tr>
<tr>
<td>Anti-fouling (TBT)</td>
<td>WZ</td>
<td></td>
</tr>
</tbody>
</table>

7.2 Quantitative pressure-impact analysis

At this moment, it was not yet attempted to find quantitative pressure-impact relationships, because there is a lack of good physical human pressure data in the coastal zone. However, for the Marine Strategy and large RWS projects (e.g. the Nature Compensation project in the Voordelta), efforts are made to quantify these physical human pressures, such as e.g. fisheries, and dredging, dumping and sand suppletion. Therefore, it is expected that in the near future these quantitative pressure-impact analyses for benthos can be made.

The observed trends in the Dutch coastal waters and the Wadden Sea are relatively small, because the water bodies are much larger than than the transitional waters and human pressures are spread out over a larger area. Therefore, it may be more difficult to find significant pressure-impact relationships in coastal waters, especially in NEA1, than in transitional waters.
8. Validation of BEQI-2 with expert judgement

In Table 4 a comparison is given of expert judgement of several Dutch marine water bodies compared with BEQI-2 EQR-values and classifications. A similar method was used for the Dutch WFD background document for phytoplankton (Van den Berg & Pot, 2007).

Table 5: expert judgement of several Dutch marine water bodies and untransformed national BEQI-2 EQR values.

<table>
<thead>
<tr>
<th>Expert judgement of</th>
<th>BEQI-2 Class a</th>
<th>Distance from G/M boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water body</td>
<td>RD</td>
<td>DdJ</td>
</tr>
<tr>
<td>Westerschelde</td>
<td>Good</td>
<td>0.68</td>
</tr>
<tr>
<td>Mesohaline-Intertidal</td>
<td>Slightly moderate</td>
<td>0.49</td>
</tr>
<tr>
<td>Eems Dollard</td>
<td>Moderate</td>
<td>0.48</td>
</tr>
<tr>
<td>Waddenzee</td>
<td>Reasonable</td>
<td>0.655</td>
</tr>
<tr>
<td>Coastal zone</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

a) A Good/Moderate boundary of 0.58 is proposed for BEQI-2 based on this expert judgement.
b) Not available

We still have to find an independent marine benthos scientist to give an expert judgement on the benthic quality of the Dutch open coastal zone. Since in the coastal zone five WFD water bodies are distinguished (Zeeuwse kust, Noordelijke Deltakust, Hollandse Kust, Waddenkust and Eems Dollard kust), and since there is a lack of clear quantitative pressure data in these regions, it is probably not an easy task to give an expert judgement on the benthic quality of these regions. In the Marine Strategy project and other RWS marine projects, new efforts are currently made to quantify human pressures on the open coastal. However, since we already have expert judgement on three important Dutch transitional and coastal water bodies, we trust that the G/M class border of 0.58 is realistic and will not be influenced by additional expert judgement on the coastal waters.

See Chapter 5.1 for information on the use a linearly transformed national BEQI-2 class borders and EQR values.
9. Comparison of BEQI-2 with m-AMBI

9.1 Comparison of BEQI-2 and m-AMBI using a phase I coastal dataset

A very good correlation between the BEQI-2 and m-AMBI is observed for the samples of Netherlands, Germany, Spain and Portugal. Especially the samples of The Netherlands, Spain and Portugal show a very high correlation, visible in the lower trend line. The German samples are in the separately visible data cluster. The BEQI-2 appears to score on average 0.0362 higher than the m-AMBI, based on the Dutch, German, Spanish and Portuguese data and using national reference values (see Figure 5).

Figure 5: Comparison of BEQI-2 (on Y-axis) with m-AMBI (on X-axis) results for 180 samples from Netherlands, Germany, Spain and Portugal. The German samples are in the upper data cluster.

\[ R = 0.937 \]
\[ P = 0.0106 \]

Figure 6: Correlation between BEQI-2 and m-AMBI for the Wadden Sea dataset (n=628), Balgzand area, spring & autumn samples

\[ R = 0.985 \]
\[ P = 0.217 \]

9.2 Comparison of BEQI-2 and m-AMBI using the Wadden Sea dataset

For 1 poolrun of 628 Wadden Sea samples, Balgzand area (Polyhaline-Intertidal) the following correlation between BEQI-2 and m-AMBI was established (see Figure 6). These results are discussed in Chapter 9.3, case 4.
9.3 Integrated discussion on comparability of BEQI-2 and m-AMBI for CW and TW

In this paragraph, all the results obtained on the comparability of BEQI-2 and m-AMBI are synthesized (see Table 5).

Table 6: Overview of correlation results for BEQI-2 and m-AMBI

<table>
<thead>
<tr>
<th>Water type</th>
<th>Water body</th>
<th>Nr Samples</th>
<th>Sample/ poole area</th>
<th>Nr samples in pool</th>
<th>R²</th>
<th>Average (BEQI-2 - m-AMBI)</th>
<th>Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transitional</td>
<td>Westerschelde</td>
<td>450</td>
<td>0.1 m²</td>
<td>7</td>
<td>0.99</td>
<td>-0.008</td>
<td>1</td>
</tr>
<tr>
<td>Transitional</td>
<td>NEAGIG common dataset</td>
<td>5900</td>
<td>0.1 or 0.01 m²</td>
<td>Ecotope-year averages</td>
<td>0.89</td>
<td>-0.009</td>
<td>2</td>
</tr>
<tr>
<td>Coastal</td>
<td>NL, DE, ES and PT</td>
<td>180</td>
<td>Various box cores</td>
<td>1</td>
<td>0.89</td>
<td>+0.03</td>
<td>3</td>
</tr>
<tr>
<td>Coastal</td>
<td>Wadden Sea</td>
<td>628</td>
<td>0.1 m²</td>
<td>1 or 2</td>
<td>0.97</td>
<td>+0.014</td>
<td>4</td>
</tr>
</tbody>
</table>

Discussion on cases:

1. In Westerschelde, a very good correlation was obtained due to the data pooling of 7 samples of 0.015 m² (see Van Loon et al., 2011). This appears to lead to a very good averaging out of BEQI-2 and m-AMBI scores. The BEQI-2 appears to score systematically -0.008 lower than the m-AMBI.

2. For the NEAGIG TW benthos dataset, again a very good correlation and small systematic difference was observed at the ecotope-year level. The BEQI-2 appears to score systematically -0.009 lower than the m-AMBI.

3. In the open Coastal zone (NEA type 1), the correlation of BEQI-2 and m-AMBI in single box core samples is remarkably good. Note that German samples represent a separate data cluster. The BEQI-2 appears to score systematically 0.03 higher than the m-AMBI. Especially the correlation and systematic agreement between the Dutch, Spanish and Portuguese results is very good (lower data point cluster).

4. In the Wadden Sea (NEA type 3/4), for the Balgzand region 628 data pools of 0.1 m² were compared using BEQI-2 and m-AMBI, using precisely the same reference conditions and AMBI class list. As in the case of the same comparison in the Westerschelde, a very high correlation (R² = 0.97) and very small systematic difference (+0.014) is observed between the EQR-scores of BEQI-2 and m-AMBI.

In conclusion, for coastal waters and in transitional waters, for cases 1 and 4 from Table 6 in which precisely the same reference conditions and AMBI classifications are used, and if the sample surface is sufficiently large (>0.065 m²), a very good correlation (R²-range 0.97-0.99) between the BEQI-2 and m-AMBI is observed at the sample level. In these cases, the systematic differences observed, calculated as the average of EQR(BEQI2) – EQR(mAMBI) scores, lie in the range of -0.008 to +0.014.

These two results show that the BEQI-2 practically gives the same EQR scores as the m-AMBI (systematic difference <2%), provided that (a) the sample size is sufficiently larger (>0.065 m², not small cores), (b) the same reference values are used and (c) the AMBI class list is the same. This comparability is very useful for (a) the intercalibration and (b) to make use of the many published results on the m-AMBI in the Dutch marine context.
10. References


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