Marine Pollution Bulletin 60 (2010) 1143–1146

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Editorial

Problems associated with the 'one-out, all-out' principle, when using multiple ecosystem components in assessing the ecological status of marine waters

1. Problems when assessing the ecological status

Recent legislation worldwide (i.e. Oceans Act in USA, Australia or Canada; Water Framework Directive (WFD) or Marine Strategy in Europe, and National Water Act in South Africa) has been developed to address ecological quality or integrity within estuarine and coastal systems (Borja et al., 2008a). The main objective of these legislative measures and policies is to maintain a good environmental or ecological status for marine waters, habitats and resources. When such good status is not achieved, the restoration of degraded aquatic habitats and ecosystems must be addressed (Apitz et al., 2006; Borja et al., 2008a). Most such legislation seeks to define quality in an integrative way by using several biological elements (i.e. phytoplankton, macroalgae, angiosperms, benthic invertebrates and fishes), together with physico-chemical and pollution elements. Such an approach permits the assessment of ecological status at the ecosystem level ('ecosystem approach' or 'holistic approach' methodologies) (Borja et al., 2008a). However, some legislation, such as the European WFD (Directive, 2000/60/EC), uses the 'one-out, all-out' (OOAO) principle in the assessment. This principle is based upon the assumption that the worst status of the elements used in the assessment determines the final status of a water body (Heiskanen et al., 2004; Borja, 2005). Hence, all the elements are monitored and assessed, using different methodologies, but if (for example) phytoplankton is in a 'moderate' status and the rest of the elements have a 'high' status (there are 5 possible levels: bad, poor, moderate, good and high), the whole water body is classified as 'moderate'. Sometimes, this approach has been misinterpreted, applying the OOAO principle at the level of the metrics within each element (i.e. nutrients and oxygen, in the physico-chemical element, in the case of García et al. (2010)), instead of at the level of the elements used in the assessment (those mentioned above), as required by the WFD.

As such, this principle entails the risk of imposing restoration costs disproportionate to the achievable environmental improvement, i.e. restoration must be made when a system does not achieve at least a good status. Moreover, the use of a large number of elements and sampling locations, within a particular water body, can amplify the risk of misclassification (Tueros et al., 2009). These problems, applying this principle, have been observed when assessing the ecological status of Danish lakes, for example (Sondergaard et al., 2005). Hence, some authors have proposed avoidance of this simplistic principle, although it may provide a useful starting point in the ecological status assessment (Moss, 2008; Borja et al., 2009c).

In a recent paper, Borja et al. (2009a) investigated the assessment of the ecological status, in an integrative way, within the Basque Country (northern Spain), using multiple ecosystem components in transitional (estuarine) and coastal water bodies. Although this was a proposal within the WFD (Borja et al., 2004), the method is not consistent with the OOAO principle. However, as most of the WFD monitoring programmes have been established in European Member States, it is time to evaluate the strengths and weaknesses of the OOAO and alternative approaches, as suggested by Noges et al. (2009). Hence, in this contribution we investigate the ecological status assessment under integrative and OOAO approaches, to study the origin of discrepancies between the approaches.

2. Methods for the assessment and reliability

The methodologies for integrating the above mentioned elements into a unique evaluation of a water body have been described in Borja et al. (2004, 2008a). These authors apply an integrative method to a series of data from 51 sampling stations, distributed amongst 18 water bodies (14 transitional and 4 coastal) of the Basque Country (northern Spain), for the period 1995–2008 (although, here, data are presented only for the period 2002–2008). The methods used to assess the status of each element are listed in Table 1.

However, some of the methods which are being used within the WFD have been developed on a local basis; they have not been tested in different geographical areas. Neither have they been used by independent authors (other than the authors of the method), nor have they been intercalibrated with other methods (Borja et al., 2007, 2009d). Hence, these points might relate to its reliability (Table 1).

3. Comparing integrative and OOAO methods

The evolution of the ecological status assessment, using the integrative method and the OOAO principle, for the Basque transitional and coastal waters is shown in Fig. 1. In coastal waters an increase in the percentage of stations in high and good status can be detected, according to the quality improvement within the region (Borja et al., 2009b; Tueros et al., 2009). This is not the case in transitional waters, where a slight increase in the percentage of moderate and poor cases can be detected, even if the quality improvement has been described also by the same authors.

The origin of this disagreement between the quality status assessed by the integrative method and by the OOAO principle has been studied, taking into account the elements involved in the assessment. In this case, it can be seen that the disagreement for coastal waters is low (23 out of 125 cases; 18%), with phytoplankton

doi:10.1016/j.marpolbul.2010.06.026

Table 1
Physico-chemical and biological quality elements used in the Basque Country for the ecological status assessment. The Table includes: (i) the name (and references) of the method used in each water category (TW: transitional waters; CW: coastal waters); (ii) if the method has been tested against different pressures; (iii) if it has been intercalibrated; (iv) if it has been tested by authors other than the proposers of the method; and (v) the reliability of the method, based upon items (ii) to (iv). Notes: W: water; S: sediment; B: biomonitors; PCQI: Physico-chemical Quality Index; CFR: Calidad de Fondos Rocosos; M-AMBI: multivariate AMBI (AZTI's Marine Biotic Index); AFI: AZTI's Fish Index. References cited: (1) Borja et al., 2004; (2) Bald et al., 2005; (3) Rodriguez et al., 2006; (4) Muxika et al., 2007; (5) Juanes et al., 2008; (6) Tueros et al., 2008; (7) Tueros et al., 2009; (8) Revilla et al., 2009; (9) Uriarte and Borja, 2009; (10) Revilla et al., 2010; (11) Borja et al., 2009a; (12) Borja et al., 2009b; (13) Guinda et al., 2008; (14) European Commission, 2008; (15) Borja et al., 2007; (16) Borja et al., 2009d; (17) Borja et al., 2008b; (18) Teixeira et al., 2008; (19) Munari et al., 2010; (20) Simonini et al., 2009; (21) Bigot et al., 2008; and (22) Martinho et al., 2008.

Elements assessed	Water category	Method (references)	Tested	Intercalibrated	Others	Reliability
Chemical	TW/CW	W/S/B – (1), (3), (6), (7)	Yes (7)	No	No	Moderate
Physico-chemical	TW/CW	PCQI – (2)	Yes (2), (11)	No	No	Moderate
Phytoplankton	TW	Basque – (10)	Yes (11)	No	No	Moderate
	CW	Spanish – (8)	Yes (8), (11)	Yes (14)	No	High
Macroalgae	TW	Basque – (1)	No	No	No	Low
	CW	CFR – (5)	Yes (5), (13)	Yes (14)	Yes (11)	High
Macroinvertebrates	TW	M-AMBI – (1), (4)	Yes (4), (11), (12)	No	Yes (17), (18), (19)	High
	CW	M-AMBI – (1), (4)	Yes (4), (11), (12)	Yes (14), (15), (16)	Yes (20), (21)	High
Fishes	TW	AFI – (1), (9)	Yes (9), (11)	No	Yes (22)	High

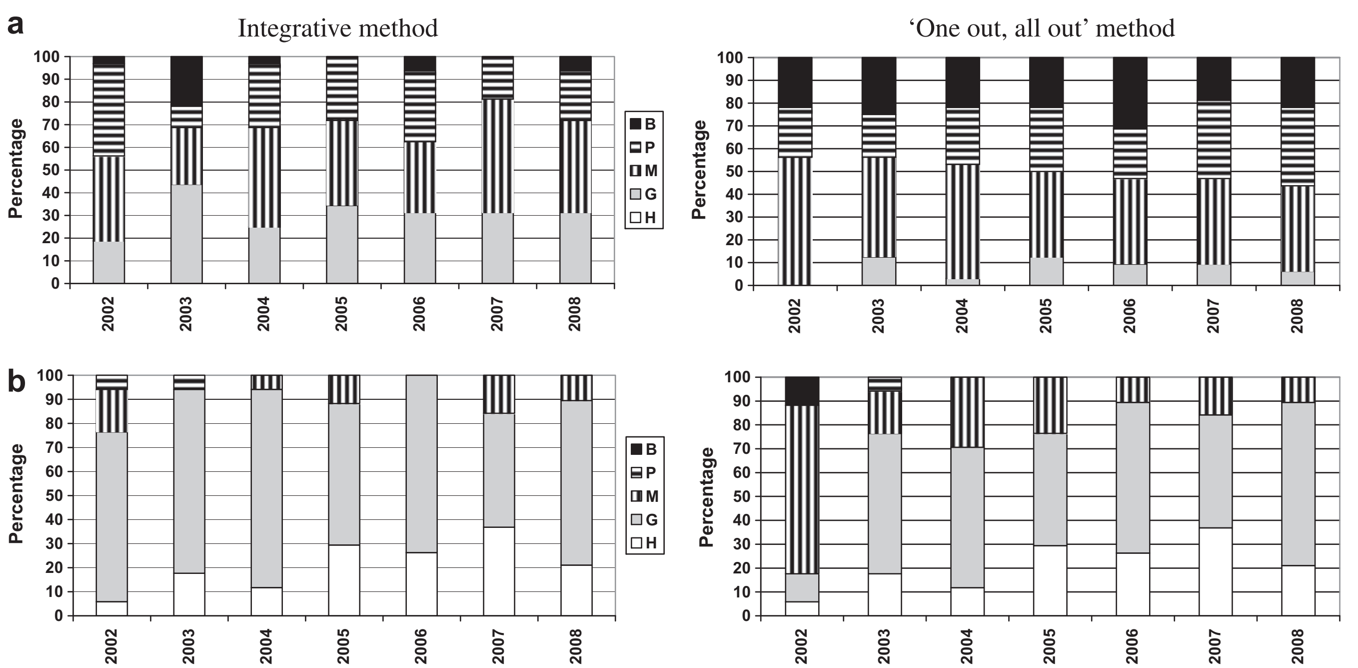

Fig. 1. Evolution of the ecological status assessment, using an integrative method (see Borja et al., 2009a) and the 'one-out, all-out' principle, for Basque: (a) transitional and (b) coastal waters. Note: H: high status; G: good status; M: moderate status; P: poor status; and B: bad status.

(14 cases) and macroalgae (6 cases) being the main elements responsible (Table 2). The number of cases of disagreement is much higher for transitional waters (130 out of 224 cases; 58%), whilst the main elements responsible are the macroalgae alone (72 cases), or macroalgae together with other elements (i.e. phytoplankton, 3 cases, and fishes, 12 cases) (Table 2). Another element producing a relative high number of disagreements (15) is phytoplankton, in transitional waters (Table 2).

Hence, when comparing the elements producing disagreement between both approaches (Table 2), combined with the reliability of the methods used in the assessment (Table 1), it can be seen that macroalgae in transitional waters have a low reliability, whilst phytoplankton in transitional waters have a moderate reliability. This finding demonstrates the importance of using reliable methods, in assessing the ecological status of aquatic systems. In fact, if macroalgae in transitional waters are removed from the analysis, the number of cases of disagreement is reduced, from 130 to 72 (32% of the 224 cases studied). Thus, the percentage of achievement of the desired ecological status, within transitional and coastal water bodies using both methods, now show the expected recovery pattern (Fig. 2b) described for several elements in the region (Borja et al., 2009b; Uriarte and Borja, 2009; Tueros et al., 2009) (Fig. 2a).

4. Need to use reliable methods

Inconsistencies similar to those described here have been observed by Moss et al. (2003) and Moss (2008), when applying the OOAO principle. This principle tends to downgrade the quality of the sites unjustifiably, depending on the number of metrics included in the assessment (Moss et al., 2003; Noges et al., 2009). Errors within individual quality elements and metrics tend to show considerable variability (Johnson et al., 2006), with it being difficult to attain adequate confidence and precision for many individual measures of biological quality (Wallin et al., 2003). If the elements are combined using the OOAO principle,

Table 2
Number of cases in which physico-chemical and biological elements are producing disagreement between the integrative method and the 'one-out, all-out' principle, for transitional and coastal waters.

Elements involved	Transitional	Coastal
Phytoplankton	15	14
Macroalgae	72	6
Phytoplankton and macroinvertebrates		1
Phytoplankton and macroalgae	3	1
Chemistry		1
Fishes	18	
Physico-chemistry	3	
Macroalgae and fishes	12	
Fishes and chemistry	4	
Phytoplankton and fishes	1	
Phytoplankton and chemistry	1	
Various	1	
Total cases with disagreement	130	23
Total cases studied	224	125

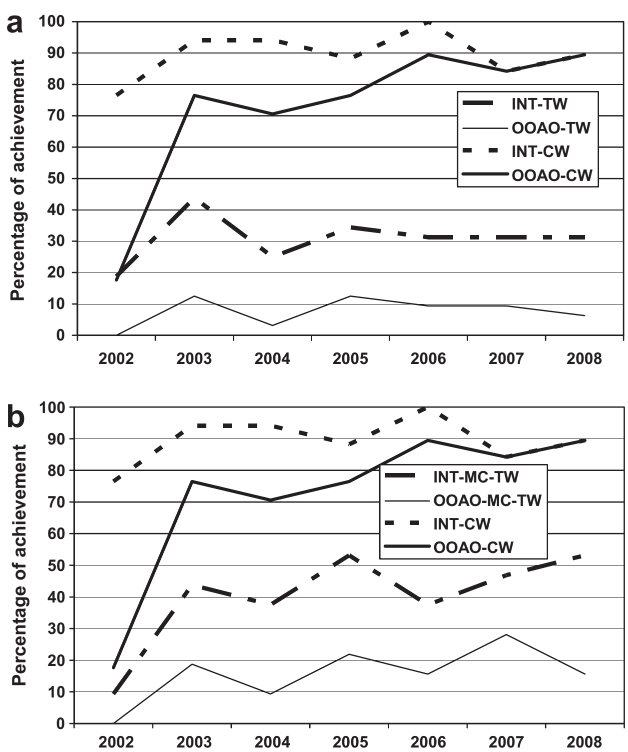

Fig. 2. Percentage of achievement of good or very good ecological status, within transitional (TW) and coastal (CW) water bodies of the Basque Country, following the two approaches used in this investigation: (i) the 'One-out, all-out' approach (OOAO); and (ii) the integrative method (INT). (a) Evolution using all the elements; and (b) evolution after removing macroalgae (MC) from transitional waters.

reliable, precise metrics tend to be overruled by less reliable metrics, for a large proportion of water bodies (Noges et al., 2009), as shown in the case of the Basque Country. Since each quality element is assessed independently of others, a high level of statistical confidence is needed for each quality element (Hatton-Ellis, 2008); this is particularly relevant in the use of the Ecological Quality Ratio (van de Bund and Solimini, 2006).

As stated by Hering et al. (2010), summarizing all sources of variability into an ecological assessment of a water body results in either Type I errors, detecting a difference when no real difference exists; and Type II errors, not detecting a difference which is real. As a Type I error increases when a Type II error is reduced and *vice versa*, provided the number of observations remains unchanged, both of these errors cannot be eliminated unless the entire population is sampled.

The OOAO principle is consistent with the precautionary principle, providing protection for the most vulnerable elements within a water body (Hering et al., 2010). At the same time, this principle will tend also to inflate Type I errors (concluding that a water body is below good status, even if the water body is really of good status), thus posing a risk of implementing measures where they are not strictly needed. As a result, the OOAO principle increases the likelihood of scoring a lower status class by sheer randomness, whereas the risk of misclassifying to a higher status (than the actual state) becomes less likely (Hering et al., 2010).

Several authors have claimed alternative approaches to the OOAO principle (Moss et al., 2003; Borja et al., 2004; Noges et al., 2009; Tueros et al., 2009). However, as the WFD is clear in terms of legally using the OOAO principle, there is no simple way to avoid this particular problem. Following the conclusions of Hering et al. (2010), options to reduce Type I errors include: (i) the selection of confidence levels for the different elements, in such a way as to minimise the risk of Type I errors (Carstensen, 2007); (ii) increase of sampling frequency or density, to reduce the variation in each element (not always possible, due to financial constraints, and, in some cases, can also increase the risk of misclassification, as demonstrated by Tueros et al. (2009)); and (iii) omitting elements with too high (not explained) variability, from the assessment. From this contribution, it seems that the later is a good approach when the reliability of methods is insufficient. Hence, an improved development and validation of the methods used within the WFD is needed, testing them over a wide range of geographical and pressure gradients, by investigators other than the developers of the methods, and conveniently intercalibrated with other European methods.

Acknowledgements

This paper is a result of the project WISER (Water bodies in Europe: Integrative Systems to assess Ecological status and Recovery) funded by the European Union under the 7th Framework Programme, Theme 6 (Environment including Climate Change) (contract No. 226273), www.wiser.eu. Data were obtained from different studies undertaken between the *Department of Environment and Land Action of the Basque Government* and AZTI-Tecnalia. We wish to thank also Professor Michael Collins (School of Ocean and Earth Science, University of Southampton, UK; and AZTI-Tecnalia) for kindly advising us on some details of this paper. This is contribution number 502 of the Marine Research Division (AZTI-Tecnalia).

References

Apitz, S.E., Elliott, M., Fountain, M., Galloway, T.S., 2006. European environmental management: moving to an ecosystem approach. Integrated Environmental Assessment and Management 2, 80–85.
Bald, J., Borja, A., Muxika, I., Franco, J., Valencia, V., 2005. Assessing reference conditions and physico-chemical status according to the European Water Framework Directive: a case-study from the Basque Country (Northern Spain). Marine Pollution Bulletin 50, 1508–1522.
Bigot, L., Gremare, A., Amouroux, J.-M., Frouin, P., Maire, O., Gaertner, J.C., 2008. Assessment of the ecological quality status of soft-bottoms in Reunion Island (tropical Southwest Indian Ocean) using AZTI marine biotic indices. Marine Pollution Bulletin 56, 704–722.
Borja, A., 2005. The European water framework directive: a challenge for nearshore, coastal and continental shelf research. Continental Shelf Research 25, 1768–1783.
Borja, A., Franco, J., Valencia, V., Bald, J., Muxika, I., Belzunce, M.J., Solaun, O., 2004. Implementation of the European water framework directive from the Basque country (northern Spain): a methodological approach. Marine Pollution Bulletin 48, 209–218.
Borja, A., Josefson, A.B., Miles, A., Muxika, I., Olsgard, F., Phillips, G., Rodríguez, J.G., Rygg, B., 2007. An approach to the intercalibration of benthic ecological status

assessment in the North Atlantic ecoregion, according to the European Water Framework Directive. Marine Pollution Bulletin 55, 42–52.
Borja, A., Bricker, S.B., Dauer, D.M., Demetriades, N.T., Ferreira, J.G., Forbes, A.T., Hutchings, P., Jia, X., Kenchington, R., Marques, J.C., Zhu, C., 2008a. Overview of integrative tools and methods in assessing ecological integrity in estuarine and coastal systems worldwide. Marine Pollution Bulletin 56, 1519–1537.
Borja, A., Dauer, D., Diaz, R., Llansó, R.J., Muxika, I., Rodriguez, J.G., Schaffner, L., 2008b. Assessing estuarine benthic quality conditions in Chesapeake Bay: a comparison of three indices. Ecological Indicators 8, 395–403.
Borja, A., Bald, J., Franco, J., Larreta, J., Muxika, I., Revilla, M., Rodríguez, J.G., Solaun, O., Uriarte, A., Valencia, V., 2009a. Using multiple ecosystem components in assessing ecological status in Spanish (Basque Country) Atlantic marine waters. Marine Pollution Bulletin 59 (1–3), 54–64.
Borja, A., Muxika, I., Rodríguez, J.G., 2009b. Paradigmatic responses of marine benthic communities to different anthropogenic pressures, using M-AMBI, within the European Water Framework Directive. Marine Ecology 30, 214–227.
Borja, A., Ranasinghe, A., Weisberg, S.B., 2009c. Assessing ecological integrity in marine waters, using multiple indices and ecosystem components: challenges for the future. Marine Pollution Bulletin 59 (1–3), 1–4.
Borja, A., Miles, A., Occhipinti-Ambrogi, A., Berg, T., 2009d. Current status of macroinvertebrate methods used for assessing the quality of European marine waters: implementing the Water Framework Directive. Hydrobiologia 633, 181–196.
Carstensen, J., 2007. Statistical principles for ecological status classification of Water Framework Directive monitoring data. Marine Pollution Bulletin 55, 3–15.
Directive 2000/60/EC of the European Parliament and the Council of 23.10.2000. A framework for community action in the field of water policy. Official journal of the European Communities 22.12.2000, 72pp.
European Commission, 2008. Commission Decision of 30 October 2008, establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise (notified under document number C(2008) 6016) (2008/915/EC). Official Journal of the European Union L332, 20–44.
García, P., Santín, C., Colubi, A., Gutiérrez, L.M., 2010. Nutrient and oxygenation conditions in transitional and coastal waters: proposing metrics for status assessment. Ecological Indicators 10, 1184–1192.
Guinda, X., Juanes, J.A., Puente, A., Revilla, J.A., 2008. Comparison of two methods for quality assessment of macroalgae assemblages, under different pollution types. Ecological Indicators 8, 743–753.
Hatton-Ellis, T., 2008. The Hitchhiker's Guide to the Water Framework Directive. Aquatic Conservation: Marine and Freshwater Ecosystems 18, 111–116.
Heiskanen, A.S., van de Bund, W., Cardoso, A.C., Nöges, P., 2004. Towards good ecological status of surface waters in Europe – interpretation and harmonisation of the concept. Water Science and Technology 49, 169–177.
Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., Feld, C.K., Heiskanen, A.S., Johnson, R.K., Moe, J., Pont, D., Solheim, A.L., van de Bund, W., 2010. The European Water Framework Directive at the age of 10: a critical review of the achievements with recommendations for the future. Science of the Total Environment 17 (7), 149–160.
Johnson, R.K., Hering, D., Furse, M.T., Clarke, R.T., 2006. Detection of ecological change using multiple organism groups: metrics and uncertainty. Hydrobiologia 566, 115–137.
Juanes, J.A., Guinda, X., Puente, A., Revilla, J.A., 2008. Macroalgae, a suitable indicator of the ecological status of coastal rocky communities in the NE Atlantic. Ecological Indicators 8, 351–359.
Martinho, F., Viegas, I., Dolbeth, M., Leitão, R., Cabral, H.N., Pardal, M.A., 2008. Assessing estuarine environmental quality using fish-based indices: performance evaluation under climatic instability. Marine Pollution Bulletin 56, 1834–1843.
Moss, B., 2008. The Water Framework Directive: total environment or political compromise? Science of the Total Environment 400, 32–41.
Moss, B., Alvarez, C., Becares, E., Van De Bund, W., Collings, S.E., Van Donk, E., De Eyto, E., Feldmann, T., Fernández-Aláez, C., Fernández-Aláez, M., Franken, R.J.M., García-Criado, F., Gross, E.M., Gyllström, M., Hansson, L.-A., Irvine, K., Järvalt, A., Jensen, J.-P., Jeppesen, E., Kairesalo, T., Kornijów, R., Krause, T., Künnap, H., Laas, A., Lill, E., Lorens, B., Luup, H., Miracle, M.R., Nõges, P., Nõges, T., Nykänen, M., Ott, I., Peczula, W., Peeters, E.T.H.M., Phillips, G., Romo, S., Russell, V., Salujõe, J., Scheffer, M., Siewertsen, K., Smal, H., Tesch, C., Timm, H., Tuvikene, L., Tonno, I., Virro, Vicente, E., Wilson, D., 2003. The determination of ecological status in shallow lakes – a tested system (ECOFRAME) for implementation of the European Water Framework Directive. Aquatic Conservation: Marine and Freshwater Ecosystems 13, 507–549.
Munari, C., Tessari, U., Rossi, R., Mistri, M., 2010. The ecological status of Karavasta Lagoon (Albania): closing the stable door before the horse has bolted? Marine Environmental Research 69, 10–17.
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.
Noges, P., van de Bund, W., Cardoso, A., Solimini, A., Heiskanen, A.-S., 2009. Assessment of the ecological status of European surface waters: a work in progress. Hydrobiologia 633, 197–211.
Revilla, M., Franco, J., Bald, J., Borja, Á., Laza, A., Seoane, S., Valencia, V., 2009. Assessment of the phytoplankton ecological status in the Basque coast (northern Spain) according to the European Water Framework Directive. Journal of Sea Research 61, 60–67.
Revilla, M., Franco, J., Garmendia, M., Borja, Á., 2010. A new method for phytoplankton quality assessment in the Basque estuaries (northern Spain), within the European Water Framework Directive. Revista de Investigación Marina doi:10.1016/j.scitotenv.2010.05.031.
Rodriguez, J.G., Tueros, I., Borja, A., Belzunce, M.J., Franco, J., Solaun, O., Valencia, V., Zuazo, A., 2006. Maximum likelihood mixture estimation to determine metal background values in estuarine and coastal sediments within the European Water Framework Directive. Science of the Total Environment 370, 278–293.
Simonini, R., Grandi, V., Massamba-N'Siala, G., Lotti, M., Montanari, G., Prevedelli, D., 2009. Assessing the ecological status of the North-western Adriatic Sea within the European Water Framework Directive: a comparison of Bentix, AMBI and M-AMBI methods. Marine Ecology 30, 241–254.
Sondergaard, M., Jeppesen, E., Jensen, J.P., Amsinck, S.L., 2005. Water Framework Directive: ecological classification of Danish lakes. Journal of Applied Ecology 42, 616–629.
Teixeira, H., Salas, F., Neto, J.M., Patrício, J., Pinto, R., Veríssimo, H., García-Charton, J.A., Marcos, C., Pérez-Ruzafa, A., Marques, J.C., 2008. Ecological indices tracking distinct impacts along disturbance-recovery gradients in a temperate NE Atlantic Estuary – guidance on reference values. Estuarine, Coastal and Shelf Science 80, 130–140.
Tueros, I., Rodriguez, J.G., Borja, A., Solaun, O., Valencia, V., Millán, E., 2008. Dissolved metal background levels in marine waters, for the assessment of the physico-chemical status, within the European Water Framework Directive. Science of the Total Environment 407, 40–52.
Tueros, I., Borja, Á., Larreta, J., Rodríguez, J.G., Valencia, V., Millán, E., 2009. Integrating long-term water and sediment pollution data, in assessing chemical status within the European Water Framework Directive. Marine Pollution Bulletin 58, 1389–1400.
Uriarte, A., Borja, A., 2009. Assessing fish quality status in transitional waters, within the European Water Framework Directive: setting boundary classes and responding to anthropogenic pressures. Estuarine, Coastal and Shelf Science 82, 214–224.
van de Bund, W., Solimini, A., 2006. Ecological Quality Ratios for ecological quality assessment in inland and marine waters. REBECCA Deliverable 10, 22pp.
Wallin, M., Wiederholm, T., Johnson, R.K., 2003. Guidance on establishing reference conditions and ecological status class boundaries for inland surface waters. Produced by CIS Working Group 2.3 – REFCOND. 93pp.

Ángel Borja *
José Germán Rodríguez
AZTI-Tecnalia Foundation, Marine Research Division, Herrera Kaia, Portualdea, s/n, 20110 Pasaia, Spain
* Corresponding author. *Tel.: +34 943004800; fax: +34 943004801.*
E-mail address: aborja@pas.azti.es (Á. Borja)