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Quality Index of Subtidal Macroalgae (QISubMac): A suitable tool for ecological quality status assessment under the scope of the European Water Framework Directive

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A B S T R A C T

Despite their representativeness and importance in coastal waters, subtidal rocky bottom habitats have been under-studied. This has resulted in a lack of available indicators for subtidal hard substrate communities. However, a few indicators using subtidal macroalgae have been developed in recent years for the purpose of being implemented into the Water Framework Directive (WFD). Accordingly, a quality index of subtidal macroalgae has been defined as a French assessment tool for subtidal rocky bottom habitats in coastal waters. This approach is based on 14 metrics that consider the depth penetration, composition (sensitive, characteristic and opportunistic) and biodiversity of macroalgae assemblages and complies with WFD requirements. Three ecoregions have been defined to fit with the geographical distribution of macroalgae along the French coastline. As a test, QISubMac was used to assess the water quality of 20 water bodies. The results show that QISubMac may discriminate among different quality classes of water bodies.

1. Introduction

According to the United Nations Environment Programme, more than 50% of the global human population is concentrated in littoral areas (less than 60 km from the shoreline). Consequently, coastal areas are impacted by human activities such as industrial and urban discharge, agriculture, natural resource exploitation, and construction. The observed degradation of marine ecosystems led to several policy decisions. In Europe, the Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD, 2008/56/EC) were implemented to evaluate and then maintain or recover good ecological status.

The Water Framework Directive (WFD) requires each member state of the European Union to achieve a good status for their surface and ground water (rivers, lakes, transitional waters, and coastal waters) by 2015 (WFD, 2000/60/EC). According to this directive, both the ecological and chemical status must be assessed. The ecological status evaluation is based on the use of biological quality elements (BQEs) and the definition of reference conditions (undisturbed or nearly so). The deviation between the observed and reference conditions is expressed as a ratio (ranging from 0 to 1), known as the ecological quality ratio (EQR). Finally, the ecological quality status (EQS) is classified into five quality classes (bad, poor, moderate, good and high) on the basis of EQR results.

To assess coastal water quality, the selected BQEs include macroinvertebrates, phytoplankton and aquatic flora such as angiosperms and macroalgae (WFD, 2000/60/EC). Macroalgae are considered to be good indicators for reflecting environmental pressures (Gorostiaga and Díez, 1996) such as eutrophication (Blomqvist et al., 2012; Eriksson et al., 2002), urban or industrial discharge (Guinda et al., 2014), and sediment inputs (Airoldi, 2003). However, very few quality assessment methods based on macroalgae had been developed until recently (Ballesteros et al., 2007). For the purpose of the WFD, subtidal macroalgae were selected to be BQEs in only a few member states, whereas the assessment methods based on intertidal macroalgae are very common. Indeed, the knowledge and available data on subtidal algae are comparatively scarce; essentially because of access difficulties (e.g. limited to diving or remotely operated vehicle access) that imply costly sampling and working difficulties. Subtidal rocky bottom are also sometimes considered as heterogeneous especially when compared with soft bottom. However, various studies that conducted careful sampling (e.g. comparable depth, sampling on flat rock, same sampling surface…) demonstrate the capacity to distinguish communities against environmental factors (Derrien-Courtel et al., 2013; Díez et al., 2003; Georg et al., 2003; Guinda et al., 2012; Kluijver, 1991; Martin, 1999; Martins et al., 2013; Pedersén and Snoeijs, 2001) or to highlight changes in relation to disturbance (Balata et al., 2007; Díez et al., 2014; Gorostiaga and Díez, 1996; Kautsky et al., 1999; Pehlke and Bartsch, 2008; Shepherd Scoresby et al., 2009). Moreover, subtidal macroalgal beds are one of the most represented habitat type in coastal shallow waters. This representativeness, the sensitivity and the functional role of subtidal macroalgae justify the needs of assessment

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method to study the relations between those benthic communities and human activities. However, only Denmark, France, Spain and Sweden designated subtidal rocky bottom macroalgae as BQEs for coastal water bodies in the northeastern Atlantic region (Birk et al., 2012). In France, macroalgae were selected as BQEs for both intertidal and subtidal rocky shores but were studied separately and the results of each evaluation are finally combined. In contrast, they are both included in a single assessment tool in Spain (Juanes et al., 2008).

Here we present an assessment tool adapted to French water bodies based on subtidal macroalgae: the Quality Index of Subtidal Macroalgae (QISubMac). As required by the WFD, the QISubMac assessment method is based on several metrics that consider sensitive and opportunistic macroalgae species. Under degraded environmental conditions (e.g., eutrophication, urban discharge), large perennial macroalgae are replaced by fast-growing opportunistic species (Arévalo et al., 2007; Benedetti-Cecchi et al., 2001; Krause-Jensen et al., 2007; Orfanidis et al., 2001). In such situations, the decrease in perennial algae (notably structuring species such as kelp or *Cystoseira* spp.) can lead to functionality loss (i.e., habitat, nursery or feeding functions) and changes in the associated fauna (Blight and Thompson, 2008; Derrien-Courtel et al., 2013; Eckman and Duggins, 1991; Edwards, 1980; Kennelly and Underwood, 1993; Moore, 1973; Schultze et al., 1990; Sheppard, 1976; Vadas and Elner, 1992).

The QISubMac assessment tool was essentially developed on the basis of the REseau BENThique (REBENT) experience. Launched in 2003, following the Erika oil spill, the REBENT programme is the first French quantitative monitoring network with large-scale data acquisition for macroalgae in subtidal zones (Derrien-Courtel, 2008; Derrien-Courtel et al., 2013). In particular, the REBENT data were used to select metrics and define the reference conditions. The use of documented metrics is in agreement with stated recommendations (Borja and Dauer, 2008).

Intercalibration of the QISubMac with the Spanish CFR method was considered during the second phase of the European intercalibration exercise at the North East Atlantic Geographical Intercalibration Group meeting in Lisbon (6–7 April 2011). The Spanish CFR was intercalibrated with the French intertidal assessment tool.

This article reports the first application of this assessment method to the coast of Brittany which is here presented as a case study. This first evaluation gives us the opportunity to test the capacity of QISubMac to distinguish the environmental status of water bodies. The relationship between environmental status and antropogenic pressure are also studied to check the relevancy of QISubMac assessment tool.

2. Materials and methods

At a large scale, the water temperature strongly varies from northern to southern French littoral. Temperature is a key parameter for macroalgae geographical distribution (Birkett et al., 1998; Breeman, 1988; Derrien-Courtel et al., 2013) and many species have their distribution limit on the French coast, such as *Laminaria digitata* (Smale et al., 2013) or *Alaria esculenta* (Dizerbo, 1947). Therefore, three ecoregions characterised by different macroalgal communities were defined. Those ecoregion correspond with the delimitation of biotypes that were defined for the needs of intercalibration of assessment method of vegetation quality elements along the North East Atlantic region (i.e. NEA 1/26-B1, NEA 1/26-B21 and NEA 1/26-A22) (Ramos et al., 2012). Then, opportunistic and characteristic species lists were adapted to correspond with those three ecoregions. We used our own biological database (the marine laboratory of Concarneau Database) and other available data such as macroalgal checklists (Chalon, 1905; Debray, 1899; Giard, 1913), bibliography (Díez et al., 2003; Gorostiaga and Díez, 1996; Juanes et al., 2008) and local expert knowledge (De Casamajor and Gevaert, personal communication).

At a smaller scale, water turbidity and sediment influence are two major factors that strongly modify macroalgal communities (depth penetration and taxa composition) (Derrien-Courtel et al., 2013; Eriksson et al., 2002; Pehlke and Bartsch, 2008). Turbidity is a somewhat complex parameter with natural (e.g., wave action, geological nature) and/or anthropogenic origins (e.g., eutrophication, dredge spoils disposal, coastal construction). Sediment input is another predominant parameter that changes algal composition by favouring silt cover-tolerant species (Airoldi, 1998; Derrien-Courtel et al., 2013; Díez et al., 2003; Gorostiaga and Díez, 1996). We have considered that the degree of exposure and dominating substrate of water bodies were two main factors that influence macroalgal communities. As an example, in very sheltered water, kelp forests disappear and are replaced by other most competitive species (e.g. *Halidrys siliquosa*, *Cystoseira baccata*…). This can affect metrics and therefore, we have created three supertypes (i.e., groups of water bodies) with specific species lists, scoring scales and reference conditions. The objective of including supertype description was to make comparison possible between water bodies with different characteristics. A comparable methodology was applied in other assessment method for intertidal shore (Neto et al., 2012). All the French water bodies type of Channel and Atlantic coast were assigned to a supertype on the basis of the analysis of hydrological parameters (e.g. level of exposure, dominating substrate) database (Creocean, 2003). All those parameters influence subtidal macroalgae composition (Derrien-Courtel et al., 2013) and then justify the definition of supertypes for the ecological status evaluation. Thus, supertype A corresponds to water bodies exposed to wave action with rocky dominating substrate, whereas supertype B groups water bodies exposed to wave action with soft bottom dominating substrate and finally, supertype C gathers water bodies characterised by sheltered condition and soft bottom dominating substrate (Table 1).

2.1. Study sites

The QISubMac was designed for the evaluation of the quality status of the water bodies along the French Chanel and Atlantic coast. This 4700 m length coastal zone (Eurosion database, 2005) is included in the North East Atlantic (NEA) region (WFD, 2000/60/EC). This coastal zone is characterised by a wide range of physical features: meso to megatidal regime, rocky sandy or muddy dominated shore, sheltered or exposed shore, homogeneous or stratified water, and shallow or deep water. The 74 water bodies of the French Chanel and Atlantic coast were characterised (DCE, 2005/11) using physical features (depth, tidal regime, current speed, level of exposure, water residence time, level of water mixing, percentage of water body occupied by the intertidal zone, and dominating substrate). Then, 33 water bodies were selected for an evaluation of their quality status. The QISubMac method was first tested on 20 water bodies from NEA 1/26-B21 biotype grouped into the 3 supertypes A, B and C. The QISubMac method was applied on 25 sampling sites (23 from Brittany WFD monitoring network and 2 additional sites) (Fig. 1) to assess the ecological status. Sampling sites were selected on the basis of their representativeness of the water body (position in the water body, presence of rocky substrate, and depth). The maximum depth was between −4 m and −40 m chart datum (C.D.). The large water bodies with rocky dominating substrate were assessed using two sampling sites, whereas one site was considered as sufficient to evaluate most of the water bodies. Moreover, results of QISubMac assessment is aggregated with other biological quality elements as intertidal macroalgae, angiosperms and opportunistic macroalgae blooms.

To represent reference conditions, seven sites characterised by a high biological status (i.e., under very low anthropogenic pressures) were selected. The lack of historical data (particularly quantitative data) on the subtidal hard substrate made the definition of this reference condition difficult. We used sites with minimally disturbed conditions (REBENT data), defined on the basis of expert judgement and an available data comparison (Derrien-Courtel et al., 2013), to represent reference conditions. Furthermore, we assume that all coastal water

Table 1
List of French water bodies type grouped into 3 supertypes.

Supertype	French type	Principal features	Dominating substrate	Degree of exposure
	C1	Shallow rocky coast with meso to macrotidal regime		
	C2	Offshore deep water body with rocky dominating subtrate		
	C14	Shallow rocky coast with mesotidal regime		
A	C15	Shallow rocky coast with macrotidal regime	Hard bottom	Exposed to very exposed
	C3	Moderately exposed muddy coast		
	C4	Exposed muddy coast		
	C6	Very exposed sandy coast		
	C7	Muddy coast with large intertidal area		
	C8	Sandy coast with mesotidal regime, mixed water		
	C9	Sandy coast with macrotidal regime, mixed water		
	C10	Sandy coast, partially stratified water		
	C11	Sandy coast with macrotidal regime		
	C13	Sandy coast, stratified water		
	C16	Mixed substrate, deep water with macrotidal regime		
B	C17	Coast with large intertidal area and patchwork substrate	Soft bottom	Exposed to very exposed
C	C12	Sheltered muddy coast	Soft bottom	Sheltered
n.a.	C5	Marine lake	n.a.	n.a.

N.A.: not attributed.

bodies are impacted by human activities (sometimes slightly) and therefore, we selected water bodies with minimum pressures. Finally, three sites were defined to represent reference conditions for both supertype A (sites 5, 10 and 16) and B (sites 1, 19 and another one at Chausey island that is not included in this study). That is comparable with other indicators as for example the Carlit method in which three reference sites are used for western Mediterranean sea (Ballesteros et al., 2007). Those reference sites were selected because of their high ecological status and their distance from main anthropogenic disturbances (industries, harbours, river basin). Concerning the very sheltered water bodies (supertype C), only two bodies were assessed for WFD with QISubMac method. Then, only one site (site 12) was designated to represent reference conditions.

In order to test the QISubMac assessment tool against anthropogenic pressures and natural variability, additional sampling site and sampling year data from other monitoring programmes such as REBENT and ELV (Loire and Vilaine Estuaries) were also analysed (N = 35). The site 17 was particularly adapted to test QISubMac against pressures because it was impacted by a maerl extraction until 2011. Then REBENT data from 2009 (during maerl exploitation) and 2012 (after the end of the maerl exploitation) were especially valuable for studying QISubMac response.

For each sampling site, a pressure level was assigned to each station according to a semi quantitative scale. The pressure level estimation was based on (i) the type of pollution (industrial or urban), (ii) the distance from the source of pollution, (iii) the magnitude of the pollution. We used the pressure assessment system used by the Northeast Atlantic Geographic Group for macroalgae (Guinda et al., 2014; JRC, 2013) to evaluate the pressure from urban discharge (Table 2). To assess the level of pressure from industrial discharge, we used a database that consider the influence of facilities classified for environmental protection (Creocean, 2003) on French coastal and transitional water bodies. We

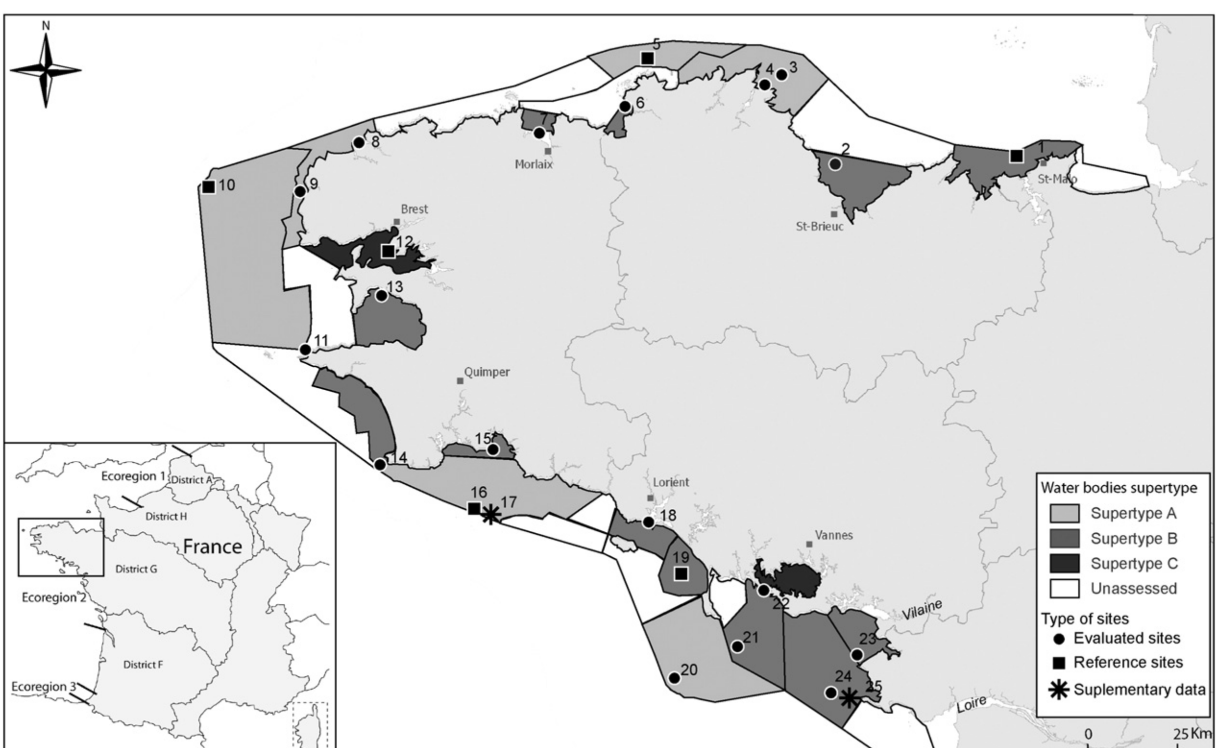

Fig. 1. Evaluated water bodies and sampling sites included in this study.

Table 2
Pressure level (PL) assessment system used.

Industrial discharge	Urban discharge	>500 m	500–100 m	100–50 m	<50 m
No pressure	>2000 IE	0	0	1	2
Low pressure	2000–10,000 IE	0	1	2	3
Intermediate pressure	10,000 IE–150,000 IE	1	2	3	4
High pressure	>150,000 IE	2	3	4	4
Diffuse pollution or other anthropogenic pressure					
No pressure		0			
Low pressure		1			
Intermediate pressure		2			
High pressure		3			
Water mixing correction factor					
Low water mixing		0			
High water mixing		−1			

PL = 0: no pressure, PL = 1: low pressure PL = 2: moderate pressure, PL = 3: high pressure PL = 4: very high pressure.

also took into account the presence of eutrophisation, dredge spoils disposal or sediment extraction near the surveyed site to estimate the diffuse pollution. Then, expert judgement was used to attribute a pressure level for diffuse pollution on the basis of the magnitude of the pressure. When several pressures were identified, we only considered the highest one. Finally, the pressure level was corrected in case of strong water mixing (tidal current, wave action) that could reduce the pollution influence. Then, five pressure levels were defined from 0 (no pressure) to 4 (high pressure). Those categories are expected to correspond with the 5 EQS.

2.2. Sampling design

Sampling was conducted during spring and summer (April–July) between 2007 and 2012. For each site, one transect was randomly positioned perpendicular to the depth gradient. Each transect's length was limited to 120 m maximum for diving safety reasons. All sampling sites were georeferenced using two GPS (Magellan eXplorist XL and Humminbird 727) to ensure precise positioning for future monitoring. A 6-year monitoring frequency was defined to assess the water body's ecological status for the WFD. However, few sites were sampled with higher frequency (sites 17, 23, 24 and 25) for the needs of other monitoring programmes (REBENT and ELV).

Divers swam along the transect to determine the upper and lower infralittoral depth limits using algal belts definition based on the density of structuring species (Castric-Fey et al., 1997, 2001, 1978, 1973; Connor et al., 2004) (Table 3). Unfortunately, at several sites the macroalgae depth penetration was limited by the lack of available hard substrate. At each site, the macroalgae community was assessed with 10 quadrats for the upper infralittoral (−1 m to −3 m C.M.) and 8 quadrats for the lower infralittoral (the depth range depended on the structuring species depth penetration). We used 0.25 m^2 (0.5 × 0.5 m) quadrats, which are commonly considered to be well adapted for macroalgae surveys (Davies et al., 2001; Derrien-Courtel et al., 2013; Eriksson et al., 2002; Kautsky et al., 1999; Martin, 1999; Martins et al., 2013; Mercer et al., 2003; Neto, 2001; Preciado and Maldonado, 2005; Rinde and Sjøtun, 2005).

Table 3
Algal belts definition.

Stage	Algal belt	Structuring species composition
Infralittoral	Sublittoral fringe	Presence of *Laminaria digitata* or *Padina pavonica*
	Upper infralittoral	Total density of structuring macroalgae (*Laminaria digitata*, *Laminaria hyperborea*, *Laminaria ochroleuca*, *Saccharina latissima*, *Saccorhiza polyschides*, *Cystoseira baccata*, *Halydris siliquosa* and *Sargassum muticum*) >3/m^2
	Lower infralittoral	Total density of structuring macroalgae (*Laminaria digitata*, *Laminaria hyperborea*, *Laminaria ochroleuca*, *Saccharina latissima*, *Saccorhiza polyschides*, *Cystoseira baccata*, *Halydris siliquosa* and *Sargassum muticum*) <3/m^2 or presence of *Solieria chordalis*
Circalittoral	Upper circalittoral	Absence of structuring macroalgae
	Lower circalittoral	Absence of all erected algae

2.3. Biological data

In each quadrat, the macroalgal taxa (attached to the rocky substrate) were recorded as close as possible to the species level. Individuals of structuring species, characteristic and opportunistic species were counted, whereas other species were only listed. The QISubMac is a non-destructive quantitative assessment method. Indeed, only a few organisms that could not be identified in the field were collected, preserved in a herbarium, and later identified in the laboratory.

Additional data were collected on the kelp species *Laminaria hyperborea*. This species is considered to be a keystone species that plays a high functional role in subtidal ecosystems with trophic resource (Leclerc et al., 2013; Norderhaug and Christie, 2011; Sjøtun et al., 1995) and micro-habitat functions (Birkett et al., 1998; Christie et al., 2003; Schultze et al., 1990; Smale et al., 2014). At sites where the perennial kelp *L. hyperborea* was present, stipe length, stipe length supporting epibionts and the total surface of epibionts attached on a stipe were measured. The surface of the epibionts was estimated as the area occupied by the epibionts onto a projected plane. Ten individuals of *L. hyperborea* were sampled in the upper infralittoral and lower infralittoral (when present).

2.4. QISubMac assessment tool

The QISubMac is composed of 14 metrics allocated among the upper or lower infralittoral. For each water body, the 14 metrics are evaluated in terms of specific scoring scales and reference sites that are adapted to a water body ecoregion (1, 2 or 3) and supertype (A, B or C).

- *Metric 1* assesses the presence (presence/absence) of the sensitive perennial macroalgae *L. digitata* (ecoregions 1 and 2), *Padina pavonica* (ecoregions 1, 2 and 3) and *Gelidium corneum* (ecoregion 3) on the entire surveyed site. If one of those species is observed, the site receives one bonus point for the upper infralittoral.
- *Metrics 2 and 3* (30-point grading scale) evaluate the maximum depth extension (in metres C.D.) of the upper and lower infralittoral, respectively. Then, the ratio between the observed depth and the historical reference depth (Table 4) is calculated. The score is obtained by multiplying the ratio by 30. When sediment covered the rocky substratum (i.e., the lower limit of the upper or lower infralittoral was limited by the lack of available hard substrate), the metric score was only included if QISubMac was improved.
- *Metric 4* (20-point grading scale) quantifies the mean density of the structuring species (numbers of individuals/m^2) assessed with 10 quadrats in the upper infralittoral. The score is a function of the mean density (Table 5).

Table 4
Reference depths (chart datum) used to mark the penetration depths of the upper and lower infralittorals (metrics 2 and 3).

Supertype	Upper infralittoral	Lower infralittoral
A	−28.4 m	−32.2 m
B	−12.5 m	−14.7 m
C	−4.2 m	−8.1 m

Table 5
Scoring scale for the density (Nb of ind/m^2) of structuring species (metric 4).

Supertype A or B	Supertype C	Score
<10	<15	0
[10; 20[	[15; 30[	5
[20; 35[	[30; 45[	10
[35; 60[	[45; 60[	15
≥60	≥60	20

- *Metrics 5 and 6* (10-point grading scale) consider the number of characteristic species in the upper and lower infralittoral, respectively (with a frequency of occurrence above 10% of the sampled quadrat) (Table 6). Then, the score is determined according to the corresponding scoring scale (Table 7).
- *Metrics 7 and 8* (10-point grading scale) examine the mean densities of opportunistic species (numbers of individuals/m^2) in the upper and lower infralittoral, respectively (Table 8). A single scoring scale was defined for those metrics (Table 7).
- *Metrics 9 and 10* (10 point grading scale) evaluate the total number of taxa identified in the upper and lower infralittoral, respectively. Table 7 provides the scoring scale.
- *Metrics 11 and 12* (10 point grading scale) are the mean *L. hyperborea* stipe length (cm) measured on 10 randomly selected individuals in the upper and lower infralittoral, respectively.
- *Metrics 13 and 14* (10 point grading scale) represent the mean quantity of epibionts that grow upon stipes (cm^2/m), which are then calculated as the ratio between the total surface of epibionts and the stipe length supporting the epibionts. Metrics 13 and 14 are measured on the same 10 *L. hyperborea* individuals as those of metrics 11 and 12. The scoring system for metrics 11, 12, 13 and 14 is presented in Table 7.

For all metrics, scoring scales were defined on the basis of WFD, REBENT and ELV data analysis. For each metric, the establishment of scoring scales was performed by the combination of the analysis of biological data from REBENT survey sites (including sites in minimally disturbed condition) and expert judgement. The majority of metrics (i.e. metrics 4 to 14) were assessed using a scale divided into 5 classes similar to WFD ecological quality status. Then, scoring thresholds between good and high class and between bad and poor class were defined on the basis of available data and expert judgement of sites representing pristine condition or degraded condition. Finally, thresholds between intermediate classes (i.e. poor/moderate and moderate/good) were defined in order to get equal intervals (Schmedtje et al., 2009). The same methodology was applied for the definition of the quality thresholds of the EQS classes.

For each site, the total score was calculated as the sum of the metrics scores (on a scale of 100 pts) for each algal belt. Then, the QISubMac was calculated as the mean of the upper and lower infralittoral total scores.

Table 6
Characteristic taxa list for the French Channel and Atlantic coast.

Algal belt	Ecoregion 1	Ecoregion 2		Ecoregion 3
	Supertypes A and B	Supertypes A and B	Supertype C	Supertypes A and B
	Ahnfeltia plicata (R)	*Acrosorium ciliolatum* (R)	*Apoglossum ruscifolium* (R)	*Callophyllis laciniata* (R)
	Erect calcareous algae (R)	Erect calcareous algae (R)	*Calliblepharis ciliata* (R)	*Champia parvula* (R)
	Apoglossum ruscifolium (R)	*Bonnemaisonia asparagoides* (R)	*Calliblepharis jubata* (R)	*Corallina* sp. (R)
	Calliblepharis ciliata (R)	*Calliblepharis ciliata* (R)	*Callophyllis laciniata* (R)	*Cystoseira* spp. (P)
	Calliblepharis jubata (R)	*Callophyllis laciniata* (R)	*Chondria dasyphylla* (R)	*Dictyopteris polypodioides* (P)
	Callophyllis laciniata (R)	*Cryptopleura ramosa* (R)	*Cryptopleura ramosa* (R)	*Dictyota dichotoma* (P)
	Cladostephus spongiosus (R)	*Delesseria sanguinea* (R)	*Cystoseira* spp. (P)	*Drachiella spectabilis* (R)
	Cordylecladia erecta (R)	*Dictyopteris polypodioides* (P)	*Dictyopteris polypodioides* (P)	*Gelidium* spp. (R)
	Cruoria pellita (R)	*Dictyota dichotoma* (P)	*Dictyota dichotoma* (P)	*Halopithys incurva* (R)
	Cryptopleura ramosa (R)	*Dilsea carnosa* (R)	*Erythroglossum laciniatum* (R)	*Halurus equisetifolius* (R)
	Dictyota dichotoma (P)	*Drachiella spectabilis* (R)	*Halidrys siliquosa* (P)	*Jania rubens* (R)
	Dilsea carnosa (R)	*Erythroglossum laciniatum* (R)	*Kallymenia reniformis* (R)	*Lithophyllum incrustans* (R)
	Erythroglossum laciniatum (R)	*Halopteris filicina* (P)	*Nitophyllum punctatum* (R)	*Nitophyllum punctatum* (R)
	Heterosiphonia plumosa (R)	*Halurus equisetifolius* (R)	*Padina pavonica* (P)	*Peyssonnelia* spp. (R)
	Laminaria digitata (P)	*Heterosiphonia plumosa* (R)	*Phyllophora crispa* (R)	*Phyllophora crispa* (R)
	Phyllophora crispa (R)	*Kallymenia reniformis* (R)	*Plocamium cartilagineum* (R)	*Plocamium cartilagineum* (R)
	Phyllophora pseudoceranoides (R)	*Laminaria hyperborea* (P)	*Polyneura bonnemaisonii* (R)	*Pterosiphonia complanata* (R)
	Phymatolithon lenormandii (R)	*Meredithia microphylla* (R)	*Pterothamnion* spp. (R)	*Pterosiphonia pennata* (R)
	Plocamium cartilagineum (R)	*Phyllophora crispa* (R)	*Rhodophyllis* spp. (R)	*Rhodymenia pseudopalmata* (R)
	Polyneura bonnemaisonii (R)	*Phymatolithon lenormandii* (R)	*Sargassum muticum* (P)	*Sphondylothamnion multifidum* (R)
	Rhodymenia pseudopalmata (R)	*Plocamium cartilagineum* (R)	*Solieria chordalis* (R)	*Stypocaulon scoparium* (P)
	Saccharina latissima (P)	*Rhodymenia pseudopalmata* (R)		*Taonia atomaria* (P)
Upper infralittoral	*Sargassum muticum* (P)	*Sphaerococcus coronopifolius* (R)		*Zanardinia typus* (P)
	Acrosorium ciliolatum (R)	*Acrosorium ciliolatum* (R)	*Apoglossum ruscifolium* (R)	Encrusting pheophyceae (P)
	Bonnemaisonia asparagoides (R)	*Bonnemaisonia asparagoides* (R)	*Bonnemaisonia asparagoides* (R)	*Calliblepharis ciliata* (R)
	Calliblepharis ciliata (R)	*Calliblepharis ciliata* (R)	*Calliblepharis ciliata* (R)	*Callophyllis laciniata* (R)
	Callophyllis laciniata (R)	*Callophyllis laciniata* (R)	*Callophyllis laciniata* (R)	*Cystoseira spp.* (P)
	Cruoria pellita (R)	*Cruoria pellita* (R)	*Chylocladia verticillata* (R)	*Dictyopteris polypodioides* (P)
	Cryptopleura ramosa (R)	*Cryptopleura ramosa* (R)	*Cryptopleura ramosa* (R)	*Dictyota dichotoma* (P)
	Delesseria sanguinea (R)	*Delesseria sanguinea* (R)	*Dictyopteris polypodioides* (P)	*Gelidium corneum* (R)
	Dictyopteris polypodioides (P)	*Dictyopteris polypodioides* (P)	*Erythroglossum laciniatum* (R)	*Halopteris filicina* (P)
	Dictyota dichotoma (P)	*Dictyota dichotoma* (P)	*Heterosiphonia plumosa* (R)	*Heterosiphonia plumosa* (R)
	Halopteris filicina (P)	*Halopteris filicina* (P)	*Nitophyllum punctatum* (R)	*Lithophyllum incrustans* (R)
	Heterosiphonia plumosa (R)	*Heterosiphonia plumosa* (R)	*Phyllophora crispa* (R)	*Mesophyllum lichenoides* (R)
	Kallymenia reniformis (R)	*Kallymenia reniformis* (R)	*Phymatolithon lenormandii* (R)	*Nitophyllum punctatum* (R)
	Laminaria hyperborea (P)	*Laminaria hyperborea* (P)	*Plocamium cartilagineum* (R)	*Peyssonnelia* spp. (R)
	Meredithia microphylla (R)	*Meredithia microphylla* (R)	*Polyneura bonnemaisonii* (R)	*Phyllophora crispa* (R)
	Phyllophora crispa (R)	*Phyllophora crispa* (R)	*Pterothamnion plumula* (R)	*Plocamium cartilagineum* (R)
	Phymatolithon lenormandii (R)	*Phymatolithon lenormandii* (R)	*Rhodophyllis divaricata* (R)	*Pterosiphonia complanata* (R)
	Plocamium cartilagineum (R)	*Plocamium cartilagineum* (R)	*Sargassum muticum* (P)	*Rhodymenia pseudopalmata* (R)
Lower infralittoral	*Polyneura bonnemaisonii* (R)	*Polyneura bonnemaisonii* (R)	*Solieria chordalis* (R)	*Zanardinia typus* (P)

Table 7
Scoring scale for the metrics 5 to 14.

Supertype	Number of characteristic species (Nb of sp.)		Density (Nb of ind/m^2) of opportunistic macroalgae		Total macroalgae biodiversity (Nb of sp.)		*L. hyperborea* stipe length (cm)		Surface of epibionts (cm^2/m of stipe)		Score (pts)
Metric	Metric 5	Metric 6	Metric 7	Metric 8	Metric 9	Metric 10	Metric 11	Metric 12	Metric 13	Metric 14	
Algal belt	Upper infralittoral	Lower infralittoral	Upper infralittoral	Lower infralittoral	Upper infralittoral	Lower infralittoral	Upper infralittoral	Lower infralittoral	Upper infralittoral	Lower infralittoral	
	<9	<5	≥30	≥30	<15	<8	<25	<3	<100	<50	0
	9–12	5–8	0–30	20–30	15–20	8–12	25–45	3–7	100–400	50–100	2.5
A	12–15	8–11	12–20	12–20	20–30	12–16	45–65	7–11	400–700	100–150	5
	15–18	11–14	7–12	7–12	30–40	16–20	65–85	11–15	700–1000	150–200	7.5
	≥18	≥14	0–7	0–7	≥40	≥20	≥85	≥15	≥1000	≥200	10
	<9	<5	≥30	≥30	<20	<15	<25	<3	<100	<50	0
	9–12	5–8	20–30	20–30	20–30	15–25	25–45	3–7	100–400	50–100	2.5
B	12–15	8–11	12–20	12–20	30–40	25–30	45–65	7–11	400–700	100–150	5
	15–18	11–14	7–12	7–12	40–45	30–35	65–85	11–15	700–1000	150–200	7.5
	≥18	≥14	0–7	0–7	≥45	≥35	≥85	≥15	≥1000	≥200	10
	<5	<5	≥30	≥30	<20	<15	<25	<3	<100	<50	0
	5–8	5–8	20–30	20–30	20–30	15–25	25–45	3–7	100–400	50–100	2.5
C	8–11	8–11	12–20	12–20	30–40	25–30	45–65	7–11	400–700	100–150	5
	11–14	11–14	7–12	7–12	40–45	30–35	65–85	11–15	700–1000	150–200	7.5
	≥14	≥14	0–7	0–7	≥45	≥35	≥85	≥15	≥1000	≥200	10

In cases where some metrics cannot be evaluated (e.g., no lower infralittoral, *L. hyperborea* absent) the score is scaled with a simple proportional calculation. When several sites represent the same water body, the mean QISubMac is calculated. Then, the EQR is provided by the ratio between the site's QISubMac and the reference QISubMac. For each supertype, we used the median value of QISubMac of selected sites that represent reference conditions that are not (or minimally) impacted by anthropogenic pressures to calculate the reference QISubMac. We used 1 to 3 reference sites to define the reference QISubMac for each supertype (Table 9). As we used the median of the QISubMac reference sites, the EQR could exceed 1. Therefore, the maximum EQR value was set to 1 to fulfil WFD requirements. Finally, the EQR result is transformed to be a EQS class (high, good, moderate, poor and bad) according to quality thresholds (Table 10).

3. Results

An analysis of the depth extension of algal belts (metrics 2 and 3) showed a large difference between sites (Fig. 2). Thus, the upper and lower infralittoral depth penetrations varied from −0.7 m to −26.3 m C.D. and from −2.5 to −29.2 m C.D., respectively. The three reference sites (sites 5, 10 and 16) for supertype A (exposed to wave action and rocky dominating substrate were characterised by deep infralittoral penetration (e.g., between −18.1 m and −26.3 m and between −23.0 m and −29.2 m C.M. for the upper and lower infralittoral, respectively). Conversely, the infralittoral depth penetration of the supertype C (sheltered condition and soft bottom dominating substrate) reference site (site 12) was limited at −4.2 m and −8.1 m for the upper and lower infralittorals, respectively. Finally, the reference sites (sites 1 and 19) of supertype B (exposed to wave action and rocky dominating substrate) showed an intermediate situation with an infralittoral depth penetration between −6.9 m and −12.5 m and between −8.4 m and −14.7 m for the upper and lower infralittorals, respectively.

The density of the structuring species (Fig. 3) varied from 10.8 ind/m^2 (site 23) to 141.2 ind/m^2 (site 9). Globally, sites of supertype A exhibited a higher density than sites of supertypes B and C.

The number of characteristic species (metrics 5 and 6) varied from 5 to 17 of the 23 characteristic species listed for the upper infralittoral and from 6 to 15 of the 18 characteristic species listed for the lower infralittoral (Fig. 4).

The opportunistic species density (metrics 7 and 8) ranged from 0 (sites 1, 5, 10) to more than 200 ind/m^2 (site 6) (Fig. 5).

The total algal biodiversity (Fig. 6) (metrics 9 and 10) also varied strongly from 18 (site 1) to 50 (site 12) for the upper infralittoral and from 11 (site 10) to 36 (site 12) for the lower infralittoral.

Finally, regarding the metrics in relation to the *L. hyperborea* epibioses (Fig. 7), the mean stipe length (metrics 11 and 12) was between 14.3 cm at site 14 and 84.3 cm at site 9 in the upper infralittoral and between 7.1 and 18.1 cm in the lower infralittoral. The quantity of epibioses (metrics 13 and 14) ranged from 25 to 900 cm^2·m^{-1}. The QISubMac scores and EQS are presented in Table 11. The EQR ranged from 0.40 (poor) to 1 (high). All of the EQS classes were represented except the "bad" class. Water bodies were primarily classified in good or high quality status. Finally, 83% of the Brittany water bodies reached WFD requirements. Three water bodies were classified in moderate class and only one water body as "poor" (FRGC44). Indeed, at site 23, the development of the macroalgal community was limited by highly turbid water. The upper infralittoral zone did not extend above the 3.1 m chart datum and the density of the structuring species was low (10.8 ind/m^2), whereas the density of the opportunistic species was high (95.2 ind/m^2).

Table 8
Opportunistic taxa list for the French Channel and Atlantic coast.

Supertypes A, B and C
Codium spp.[a]
Cladophora spp.[a]
Enteromorpha spp.
Ulva spp.
Diatoms filamentous colony
Desmarestia ligulata
Ectocarpales
Hincksia spp.
Ceramium spp.
Hypoglossum hypoglossoides
Heterosiphonia japonica
Polysiphonia spp. (exept *P. lanosa* and *P. elongata*)

[a] not considered as opportunistic in Ecoregion 3.

Table 9
Reference QISubMac (median of the reference sites QISubMac) for each supertype.

	Supertype A	Supertype B	Supertype C
Reference site 1	87.0	54.4	80.8
Reference site 2	70.9	56.8	
Reference site 3	74.8	60.7	
Reference QISubMac	74.8	56.8	80.8

Table 10
EQR thresholds for quality status assignment.

EQR	EQS
0.85–1	High
0.65–0.85	Good
0.45–0.65	Moderate
0.25–.0.45	Poor
0–0.25	Bad

Globally, the EQS showed good correspondence with the estimated pressure level. Indeed, 78% of the classifications of the water bodies were in accordance with the expected results. However, three water bodies (representing 13% of the evaluated water bodies) were overestimated and were classified in high despite a pressure level of 1. Moreover, two water bodies (representing 9% of the evaluated water bodies) obtained a good status classification whereas a high status was expected. Finally, only one water bodies was declassified with a moderate status (just above the moderate-good quality threshold).

The correlation between EQR calculated with QISubMac assessment tool and pressure level assigned to the stations was significant ($R^2 = 0.74$, $p < 0.001$) (Fig. 8.). Moreover, QISubMac showed a positive reaction to the end of the maerl exploitation with a quality status that improved from moderate to good (Table 11).

4. Discussion

The QISubMac assessment tool respects the WFD basic requirements that impose to assess composition and abundance of macroalgae (e.g. presence of sensitive species, biodiversity, density of opportunistic algae and number of characteristic species).

The QISubMac assessment tool is based on 14 metrics, each with a different weight in the final score. Metrics 2 and 3 (depth penetration of the upper and lower infralittoral) are assessed on a 30-point scale and metrics 9 and 10 (total diversity) are evaluated on a 10-point scoring scale. More weight is given to metrics 2 and 3 because the macroalgae depth penetration is considered to be a very good indicator of water turbidity. This was confirmed by REBENT data analysis (Derrien-Courtel et al., 2013). Concerning the total algal biodiversity metrics, we assume that this parameter is important. However, we observed that total algal diversity is not always characterised by a positive linear correlation with ecological status. Of course, algal biodiversity typically strongly decreases in highly polluted areas; however, algal diversity does not necessarily reach its maximum value in undisturbed conditions. Indeed, little disturbance, such as suspended matter input, generally favours macroalgal diversity with the apparition of silt tolerant species (Díez et al., 2003). Our results confirm this theory. Indeed, reference sites 5, 10 and 16 for supertype A located offshore with minimally disturbed conditions have low or medium biodiversity, whereas coastal sites with sediment influence such as sites 7 and 12 show important algal biodiversity. Therefore, we decided to give less importance to algal biodiversity metrics in the final score.

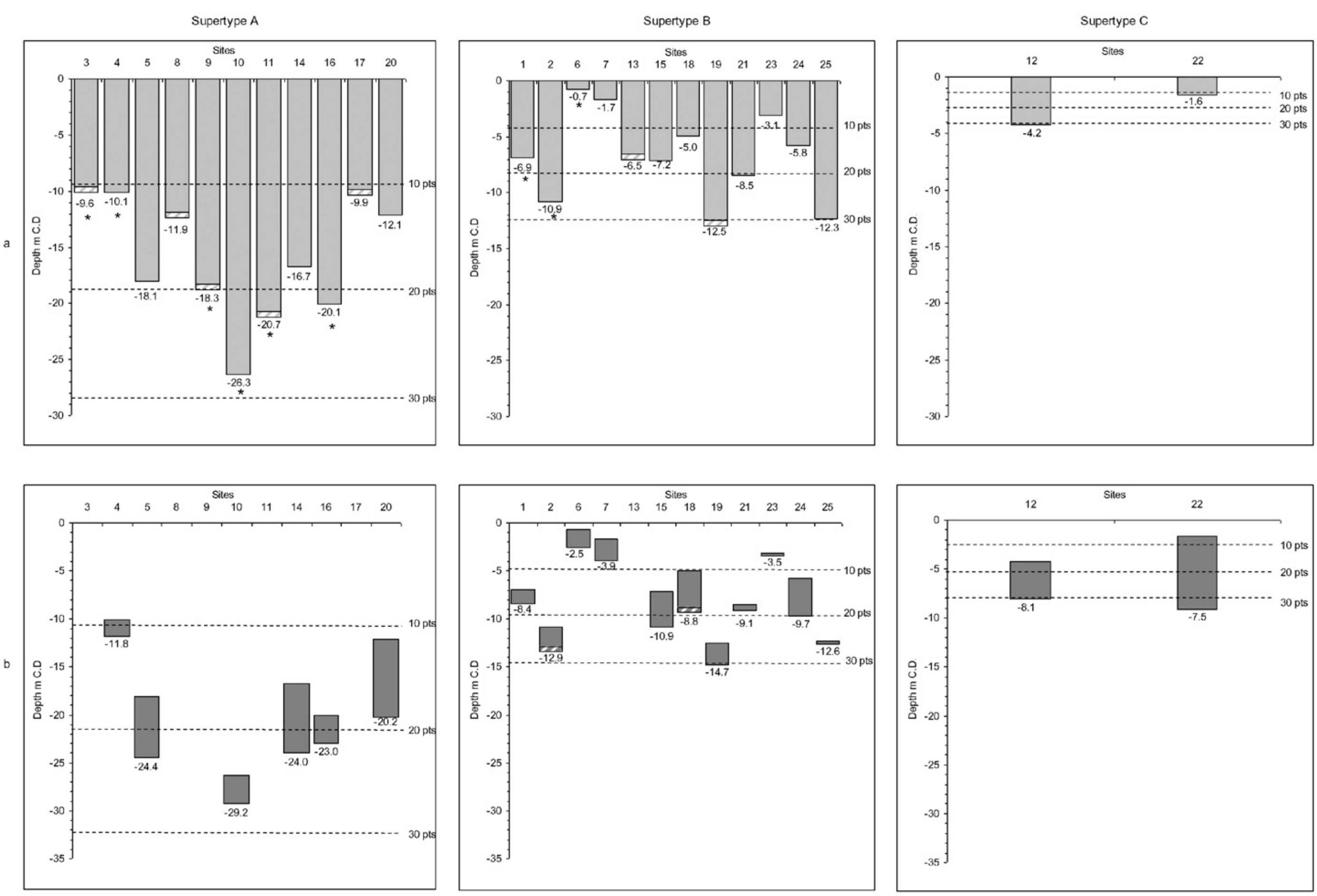

Fig. 2. Extension of upper (a) and lower (b) infralittorals (metrics 2 and 3) for sites of supertypes A, B and C (respectively, from the left to the right) The scoring scale (continuous) is represented for each algal belt and supertype. Slanted stripes signify that the lower limit of the upper or lower infralittorals was limited by the lack of an available hard substrate. The presence of a sensitive perennial species (*Laminaria digitata*, *Padina pavonica* or *Gelidium corneum*) (metric 1) is also indicated (*).

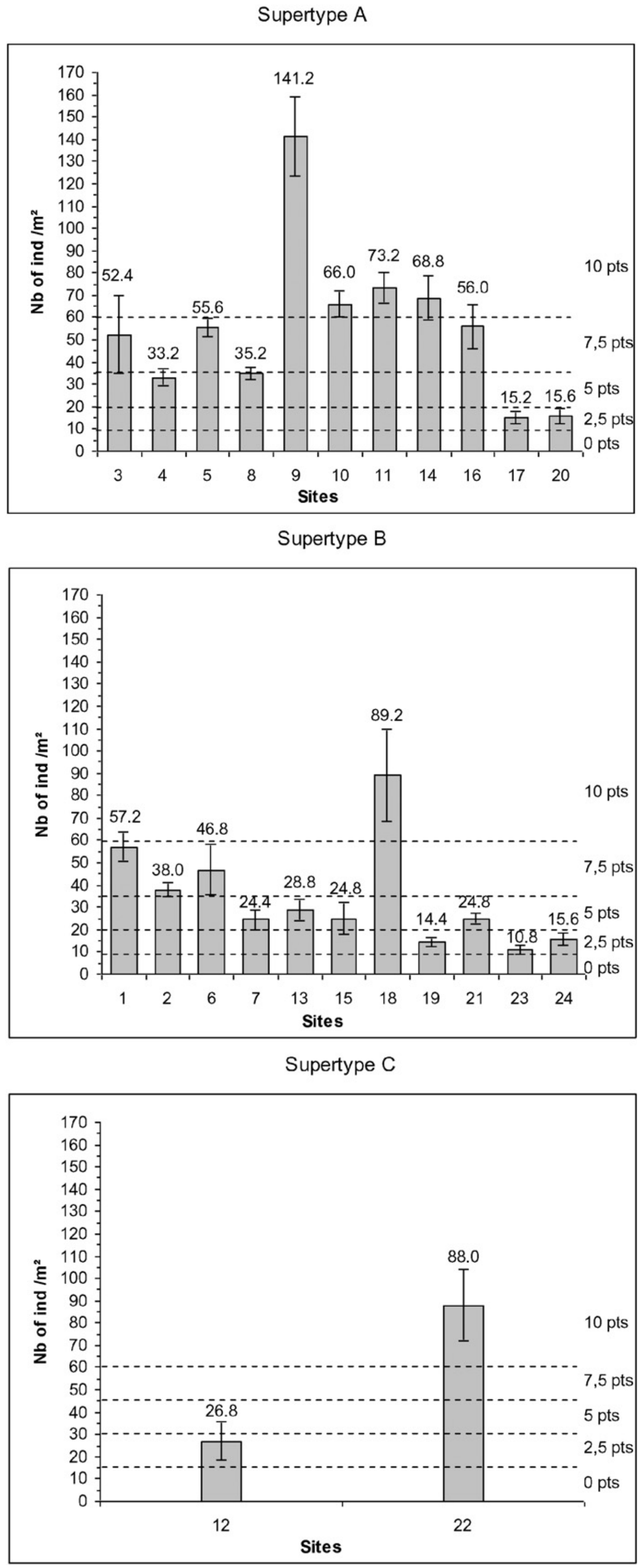

Fig. 3. Average density of the structuring species in the upper infralittoral (metric 4) for sites of supertypes A, B and C (respectively, from the top to the bottom) The scoring scale (discontinuous) is represented for each supertype.

Globally, QISubMac assessment tool has provided a good evaluation of the quality of the water bodies with a significant correlation between the pressure level and the assigned quality status. Moreover, in most cases, supplementary data from other monitoring programmes has showed the capacity of QISubMac to give constant EQS to sites with several sampling years (except when pressure level has changed in time as for site 17). However, some EQS variations were observed from site 23 that was classified alternatively in poor or moderate classes. A probably explanation could be the variability of the Vilaine estuary influence depending on years. Indeed, the high pluviometry years could cause mud deposition on subtidal rocky bottom that could influence algal composition. The Loire-Vilaine estuaries (ELV) programme was especially designed in order to assess the influence of estuaries on rocky subtidal communities with a high frequency sampling (every year against once every 6 years for WFD in France). Results of ELV programme suggest that the proximity of a large estuary should be integrated in scoring system in order to avoid underestimation of quality status. Moreover, a major concern during the evaluation of the ecological quality status is to distinguish between the variability due to anthropogenic impacts and natural variability. Macroalgae development can be affected by several environmental parameters (e.g., storms, pluviometry) that vary from one year to another. The monitoring of reference condition sites (i.e., minimally impacted by human activities but potentially subject to environmental variation) is specifically designed to partition the anthropogenic from the natural variability. Time series will also provide additional valuable information for this task. For this purpose, some sites were selected for annual monitoring of the depth penetration of algal belts (metrics 2 and 3) and the density of structuring species (metric 4). The annual assessment of parameters concerning structuring species was motivated by the quicker changes observed for those species in comparison with the under-canopy macroalgae (Kennelly, 1987; Lilley and Schiel, 2006; Melville and Connell, 2001). Therefore, the decision was made to increase the frequency of sites monitoring from 6 to 3 years for complete monitoring and to 1 year for partial monitoring of the few sites that show strong annual variability (metrics 2, 3 and 4) for the French WFD second management plan.

The first results confirmed the capacity of the QISubMac assessment tool to discriminate the ecological status of the sites with different environmental situations. Indeed, adjacent water bodies can exhibit a very different EQS. The case of water bodies FRGC44 (site 23) and FRGC45 (site 24) is representative of this situation. Indeed, site 24 is classified as “good”, whereas the EQS of site 23 is found to be “poor”. Those two sites are both influenced by the Loire estuary, but site 23 is also affected by the daily Vilaine estuary dam release that provides an influx of mud and increases water turbidity. The Bay of Vilaine is also disturbed by phytoplankton blooms that decrease water transparency and sometimes result in an anoxic phenomenon. Site 24 is located further offshore and is expected to be less perturbed. The EQS attributed to this site is “good”, which is consistent with our expectations. The analysis of sites 23 and 24 shows that, as expected, the results of the macroalgal depth penetration, density of structuring algae, number of characteristic species and density opportunistic species in the upper infralittoral (metrics 2, 4, 5, and 7) are better for the less disturbed site (site 24). The densities of the opportunistic species in the lower infralittoral (metric 8) are approximately equal between the two sites, whereas the total algal biodiversity is greater (metrics 9 and 10) at site 23. This last result is consistent with our expectation. Finally, although these two sites are closely located, environmental conditions (water turbidity, muddy inputs from Vilaine estuary) prevent the development of *L. hyperborea* (metrics 11, 12, 13 and 14) (Derrien-Courtel et al., 2013).

The QISubMac method was first applied in the Loire-Brittany hydrographic district (District G) and then was extended to the three other hydrographic districts. The wide area of application of the QISubMac, ranging in latitude from 50° 50′N to 43° 23′N, implied an adaptation of the characteristic species list. Indeed, it was necessary to develop a method that could be applied to the entire French Chanel and Atlantic coasts because of the variability of the characteristics of the water bodies such as the water temperature that influences the geographical distribution of macroalgae (Birkett et al., 1998; Derrien-Courtel et al.,

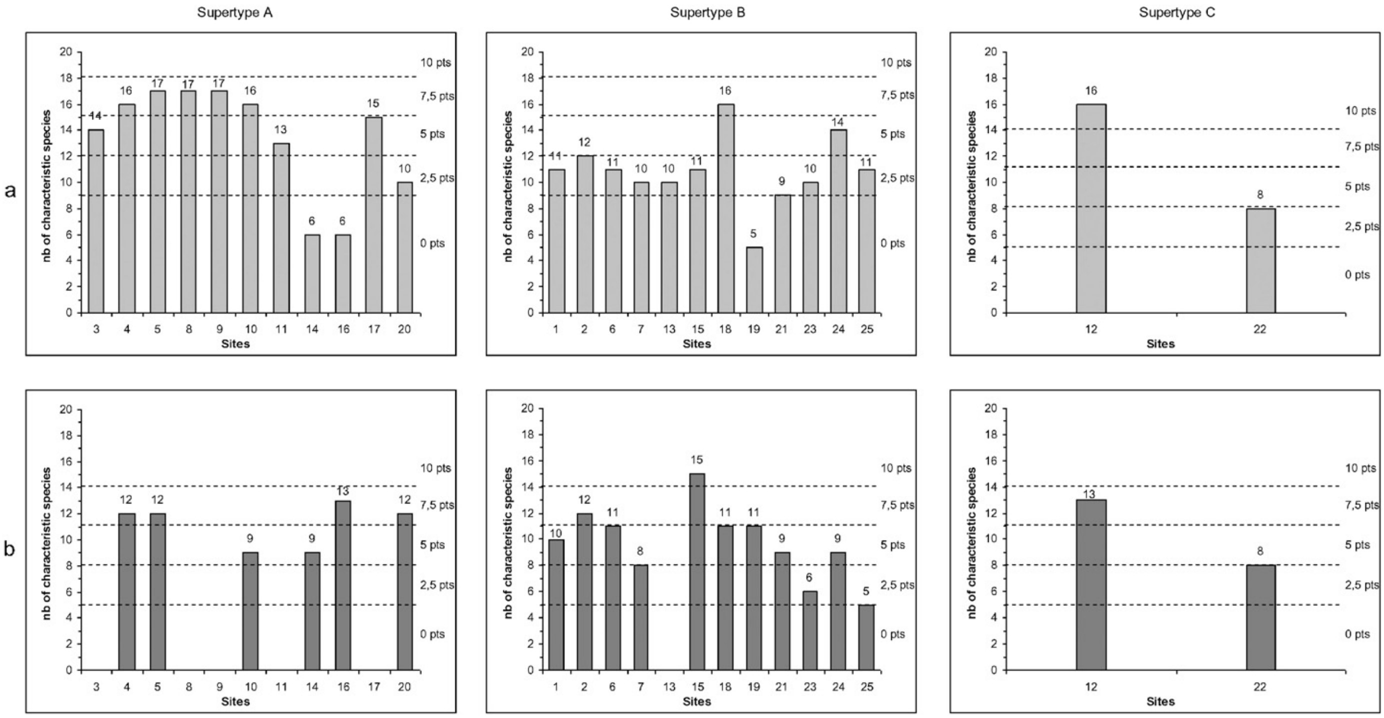

Fig. 4. Number of characteristic species in the upper (a) and lower (b) infralittorals (metrics 5 and 6) for sites of supertypes A, B and C (respectively, from the left to the right) The scoring scale (discontinuous) is represented for each algal belt and supertype.

2013; Lüning, 1984). The three ecoregions defined for QISubMac assessment tool are in accordance with the coastal classification established on the bases on abiotic (Ramos et al., 2012) and intertidal macroalgae data (Ramos et al., 2014). Furthermore, metrics concerning *L. hyperborea* parameters (i.e., metrics 11, 12, 13 and 14) could not be studied at some sites and, more generally, at the complete hydrographic district (e.g., district F) because of the geographical distribution of this species.

The QISubMac assessment tool was presented at the North East Atlantic Geographical Intercalibration Group, Macroalgae and Angiosperms meeting in Lisbon (6–7 April 2011). The comparison of the QISubMac with the Spanish assessment tool (CFR) showed that 23 of the 28 characteristic species for the subtidal environment are common with the QISubMac characteristic and structuring species lists (Guinda et al., 2014). Nevertheless, some differences also appeared with *Desmarestia ligulata*, which is considered to be characteristic in CFR, whereas it was classified as opportunistic in QISubMac based on REBENT data (Derrien-Courtel, 2008) and a bibliography (Edwards, 1998). Another point of disagreement concerns *Sargassum muticum*, which is defined as invasive using the CFR, whereas it was listed as a structuring species in QISubMac. This non-native species was probably introduced along the French coast in the 1970s and has been a very invasive species for a number of decades. However, this algae no longer expands along French coastal areas today, and has even disappeared from some localities (Belsher, 1991). Even if the presence of *S. muticum* still causes locally some disagreement especially for boat cruising, this species also play a positive role into the subtidal ecosystem. Indeed, *S. muticum* is particularly competitive in environment where other structuring phaeophyceae (e.g. *Laminaria* spp. or *Cystoseira* spp.) cannot settle because of the high turbidity, the mobility of the substrate (small pebble), the sediment influence and low hydrodynamism (Le Lann, 2009). Then, in those environments, *S. muticum* creates a canopy and plays a functional role for various organisms as small crustacean, fish larva or algae and invertebrate that can settle on *S. muticum* thallus. Even if this species is an introduced species, *S.* muticum have found its ecological niche. Therefore, *S. muticum* can now be considered a structuring species (Karlsson, 1997). Finally, a comparison of the CFR and QISubMac assessment tools revealed different philosophies in these indicators. Indeed, CFR uses semi-quantitative metrics and is, therefore, well-adapted for the extensive evaluation of subtidal rocky shores (Guinda et al., 2014) whereas QISubMac is a very precise assessment method based on numerous quantitative metrics.

As a BQE, subtidal macroalgae represent a pressure integrator. The QISubMac assessment tool is mostly suitable for detecting pressures that imply turbidity, sediment inputs, eutrophisation and thus, is adapted to the main environmental issues encountered in French coastal areas. Indeed, French water bodies are concerned with phytoplankton blooms caused by eutrophication, dredge spoils disposal, coastal construction that affects sedimentation (e.g., marinas and dams) and the extraction of granular material (e.g., maerl or sand). All of those problems increase the water turbidity and in turn influence the depth penetration (metrics 2 and 3) and density (metric 4) of macroalgae, especially for structuring species such as kelps, *Cystoseira baccata* and other large pheophyceae (Derrien-Courtel et al., 2013). The relationship between the identified pressures and metrics is still currently being addressed, and the correlation between the pressures and each metric is being tested. Our main objective consists in testing QISubMac against high level pressures in the future. In that sense, a research project has been developed in order to test the influence of waste water treatment plant outfalls on rocky subtidal communities using the QISubMac assessment tool.

Assessing the environmental status of water bodies with very different features represents a challenge because macroalgal communities are very different according to the environmental parameters. The QISubMac assessment tool takes two major water bodies features (degree of exposure and dominating substrate) into account with the creation of the supertypes. Indeed, those parameters strongly influence macroalgal communities. The use of three supertypes gives us the possibility to adapt our scoring scale to the potential of each water bodies. However, in the case of supertype C, we assume that all the water bodies are affected by human activities. Indeed, these water bodies are generally influenced by estuaries and located in sheltered areas. Various

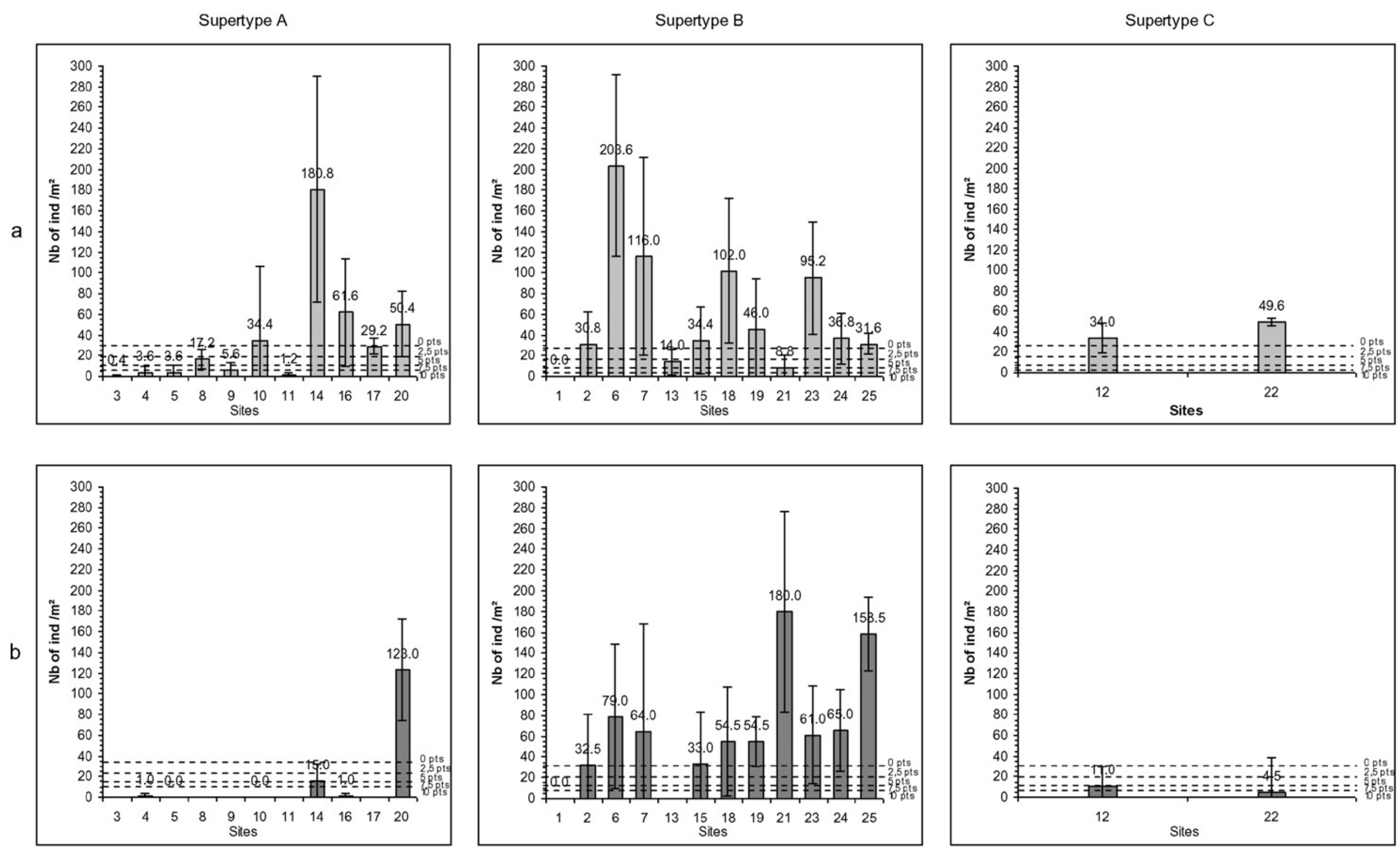

Fig. 5. Average density of opportunistic species in the upper (a) and lower (b) infralittorals (metrics 7 and 8) for sites of supertypes A, B and C (respectively, from the left to the right). The scoring scale (discontinuous) is represented for each algal belt and supertype.

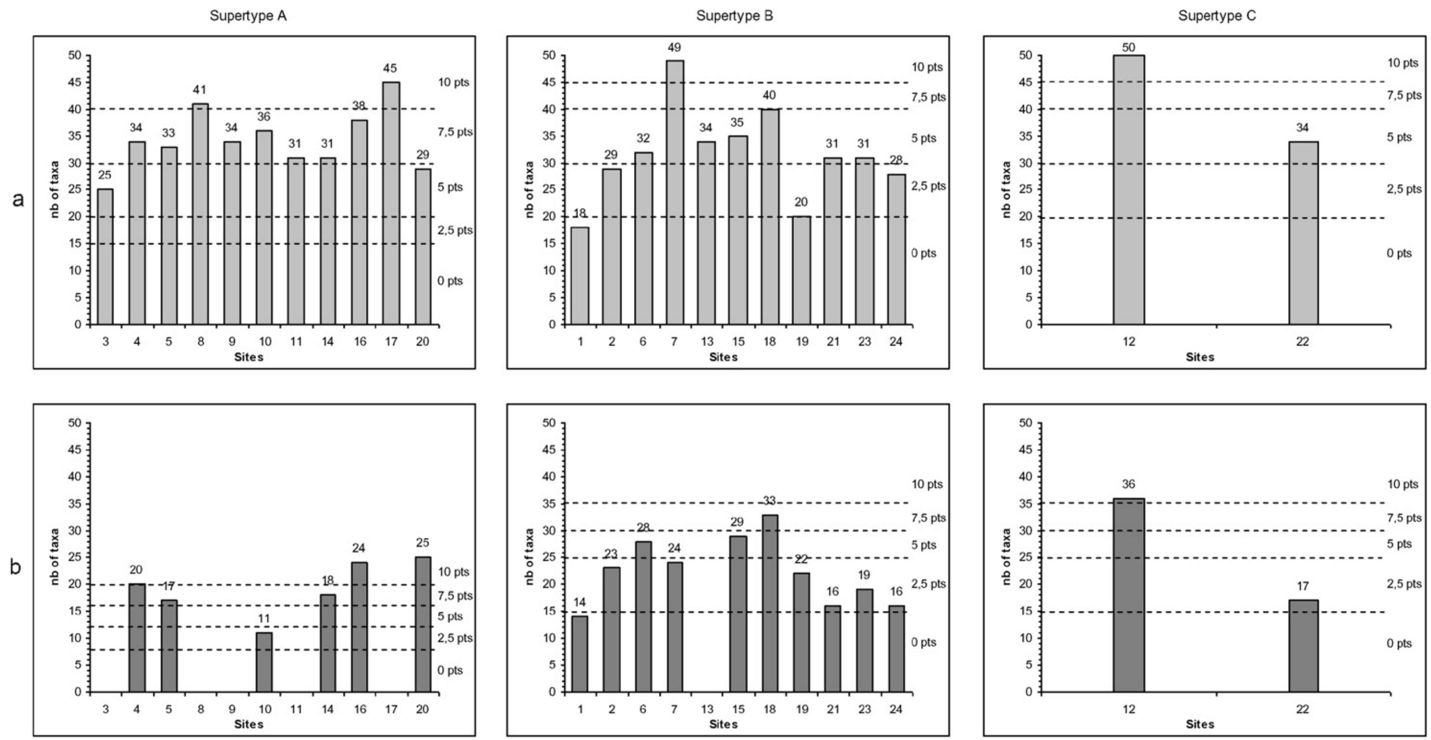

Fig. 6. Total taxa richness in the upper (a) and lower (b) infralittorals (metrics 9 and 10) for sites of supertypes A, B and C (respectively, from the left to the right) The scoring scale (discontinuous) is represented for each algal belt and supertype.

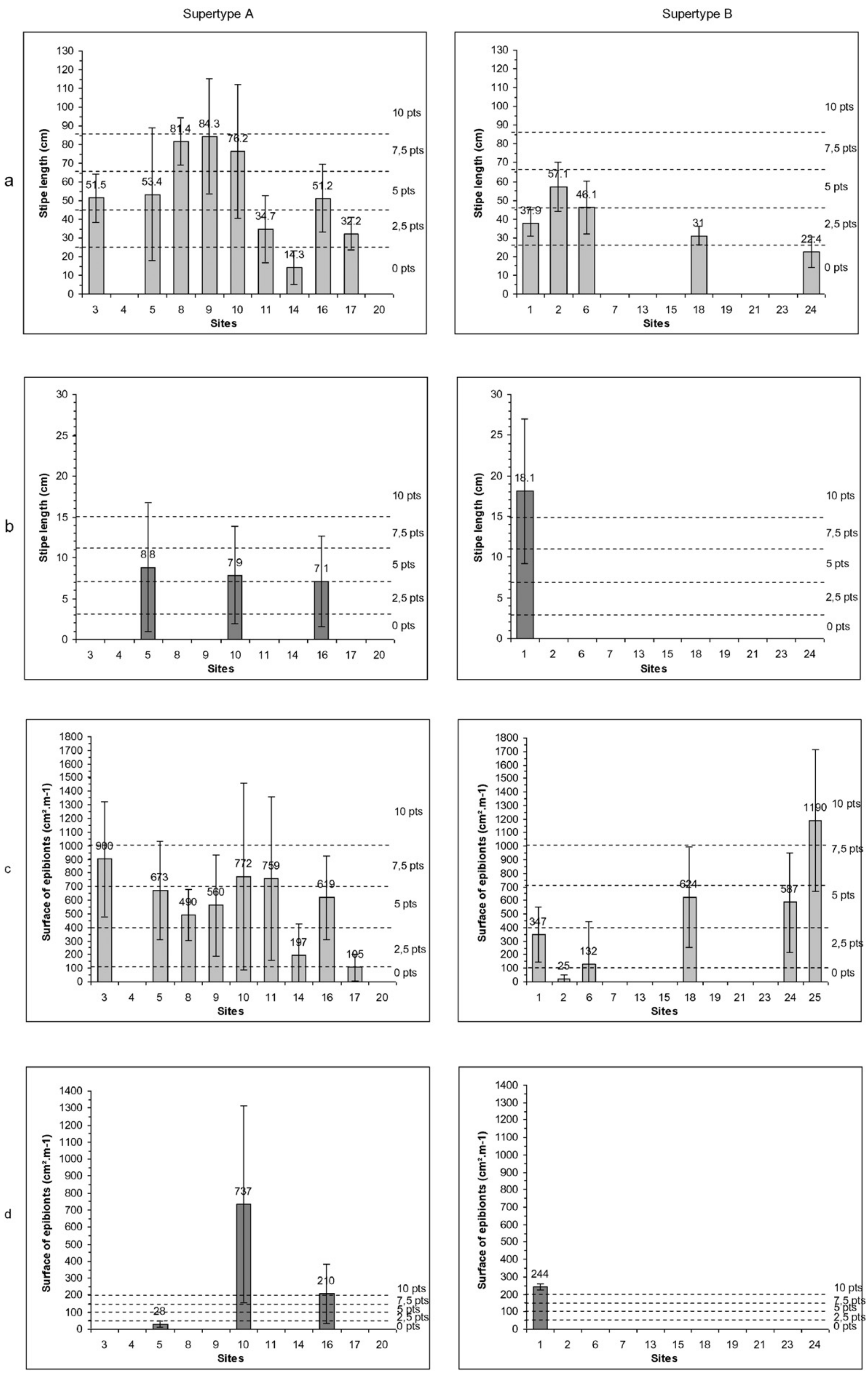
Supertype A
Supertype B
a
b
c
d
Stipe length (cm)
Surface of epibionts (cm².m-1)
Sites
10 pts
7,5 pts
5 pts
2,5 pts
0 pts

Table 11
Results of the application of the QISubMac tool.

Site	Site	National water body code	Supertype of water bodies	Sampling year	Upper infralittoral total score (/100 pts)	Lower infralittoral total score (/100 pts)	QISubMac (/100 pts)	EQR	EQS	Pressure level
1	Les Haies de la Conchée	FRGC03	B	2008	50.1	65.1	57.6	1.00	H	0
2	Rohein	FRGC05	B	2008	54.6	60.5	57.6	1.00	H	0
3	La Pointe du Paon	FRGC07	A	2008	69.3	n.d.	69.3	0.93	H	0
4	Moguedhier	FRGC07	A	2008	58.4	64.2	61.3	0.82	H	1
5	La Barrière	FRGC08	A	2009	70.1	66.0	68.1	0.91	H	0
6	Roc'h Mignon	FRGC10	B	2009	32.7	29.3	31.0	0.55	M	2
7	Le Corbeau	FRGC11	B	2008	33.1	25.8	29.5	0.52	M	2
8	îles de la Croix	FRGC13	A	2007	71.4	n.d.	71.4	0.95	H	0
9	Liniou	FRGC13	A	2007	83.6	n.d.	83.6	1.00	H	0
10	Ar Forc'h Vihan	FRGC18	A	2009	78.7	74.6	76.7	1.00	H	0
11	Pointe du Van	FRGC18	A	2008	76.4	n.d.	76.4	1.00	H	0
12	Ile Ronde	FRGC16	C	2009	70.0	91.7	80.8	1.00	H	1
13	île de l'Aber	FRGC20	B	2008	47.9	n.d.	47.9	0.84	G	1
14	Gaouac'h	FRGC26	A	2008	47.6	66.3	57.0	0.76	G	0
15	Linuen	FRGC29	B	2009	43.4	61.8	52.6	0.93	H	1
16	Les Bluiniers	FRGC28	A	2009	54.5	79.9	67.2	0.92	H	0
17	Pen a Men	FRGC28	A	2009	40.4	n.d.	40.4	0.54	M	2
17	Pen a Men	FRGC28	A	2012	61.4	n.d.	61.4	0.82	G	0
18	Bastresse Sud	FRGC34	B	2007	54.5	54.8	54.7	0.96	H	1
19	Pierres Noires	FRGC35	B	2008	46.9	66.7	56.8	1.00	H	0
20	Pointe du Grand Guet	FRGC42	A	2008	31.6	60.5	46.1	0.62	M	0
21	Le Grand Coin	FRGC38	B	2008	56.8	43.3	50.0	0.88	H	0
22	Tourelle de Grégam	FRGC39	C	2008	51.9	79.2	65.5	0.81	G	1
23	Ile Dumet	FRGC44	B	2008	25.0	20.0	22.5	0.40	P	3
23	Ile Dumet	FRGC44	B	2009	33.6	29.2	31.4	0.55	M	3
23	Ile Dumet	FRGC44	B	2010	13.7	15.5	14.6	0.26	P	3
23	Ile Dumet	FRGC44	B	2011	24.0	32.8	28.4	0.50	M	3
23	Ile Dumet	FRGC44	B	2012	14.6	15.3	15.0	0.26	P	3
24	Plateau du Four	FRGC45	B	2008	31.3	45.3	38.3	0.67	G	0
24	Plateau du Four	FRGC45	B	2009	57.5	66.7	62.1	1.00	H	0
24	Plateau du Four	FRGC45	B	2010	46.2	57.3	51.7	0.91	H	0
24	Plateau du Four	FRGC45	B	2011	51.0	65.1	58.0	1.00	H	0
24	Plateau du Four	FRGC45	B	2012	45.1	56.2	50.7	0.89	H	0
25	Goue Vas	FRGC45	B	2009	57.2	54.2	55.7	0.98	H	0
25	Goue Vas	FRGC45	B	2011	65.0	n.d.	65.0	1.00	H	0

H: High, G: Good, M: Moderate, P: Poor, B: Bad; Underlined site numbers represent reference condition sites.

human activities such as shellfish aquaculture or marinas benefit from this situation. Furthermore, all rivers are more or less affected by agriculture or industrial activities. Then, the reference site used for the evaluation of sites that belong to supertype C is also certainly impacted by human activities. Nevertheless, we estimate that the use of a potentially impacted site as reference will lead to better results than using a reference site of supertype A or B where macroalgal community is not comparable.

In compliance with the WFD (WFD, 2000/60/EC), QISubMac is only based on macroalgae communities. Nevertheless, on rocky substrates, macroalgae are strongly linked with associated invertebrates and spatial competition occurs between fauna and flora. Generally, in clear shallow water, macroalgae are essentially dominant. When the available light decreases, such as in turbid conditions, invertebrates become more abundant (Derrien-Courtel et al., 2013; Glasby, 1999; Kluijver, 1991; Saiz-Salinas and Urkiaga-Alberdi, 1999). Based on this observation, a survey of invertebrates was added to the French WFD monitoring programme for a rocky subtidal seabed in the context of the second management plan (2014–2020). The objective is to reinforce EQS evaluation. In this perspective, the first step consists of data acquisition. Analyses will be conducted to develop an effective indicator that takes faunal composition into consideration such as the method developed on Spanish Basque coast for intertidal rocky shore (Díez et al., 2012). However, because the fauna of a rocky bottom are not selected as a BQE for rocky substrate in France, the results will not be included in the French WFD reports. The fauna data analysis will only be considered as reinforcement for the quality evaluation of water bodies. We are convinced that a global monitoring of subtidal hard bottom flora and fauna better reflects the complexity of the ecosystem (Van Hoey et al., 2010) and is better adapted to the purpose of the future Marine Strategy Framework Directive (2008/56/EC).

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Fig. 7. Average *L. hyperborea* stipe length in the upper (a) and lower (b) infralittoral (metrics 11 and 12) and average surface of epibionts in the upper (c) and lower (d) infralittoral (metrics 13 and 14) for sites of supertype A and B (respectively, from the left to the right) Sites of supertype C were not represented because of the lack of *L. hyperborea*.The scoring scale (discontinuous) is represented for each algal belt and supertype.

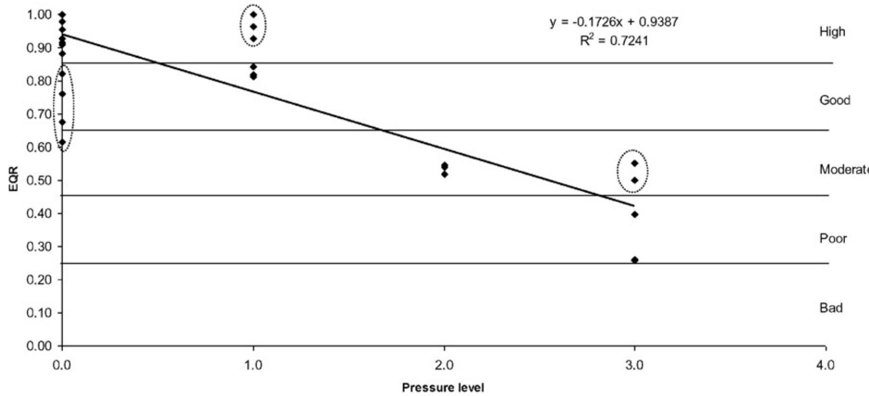

Fig. 8. Correlation between the pressure level of the stations and the Ecological Quality Ratio obtained with QISubMac assessment tool Corresponding ecological quality status is indicated on the right. Data located into ellipse correspond to over or under estimation of quality status.

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