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Epifaunal inventory of two shipwrecks from the Belgian Continental Shelf

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Abstract

Shipwrecks are almost the only subtidal substrata available for epifaunal colonization along the Belgian coastal waters and have never been scientifically prospected up to now. Two shipwrecks have been investigated during the summers of 2001 and 2002. *De-visu* observations and examination of 14 scraped surfaces of 0.0625 m^2 allowed the identification of a total of 121 macrofauna species. Species richness cumulative curves provide an estimated number of 150–280 species. Both shipwrecks are dominated by Cnidarians. The tube-dwelling amphipod *Jassa herdmani* was also particularly abundant. Striking differences were observed between shipwrecks. Different faunal assemblages were observed on vertical and horizontal surfaces. Species richness could not been correlated with diversity indices. Samples with high species diversity were observed when the Hydrozoan *Tubularia indivisa* was dominant. On the contrary, when the Anthozoan *Metridium senile* was dominant, samples showed a very low species richness. Finally, the Poriferan *Dysidea fragilis* has to be considered as a new species for the Belgian fauna.

Introduction

Since the second part of the 19th century, the benthos of the Southern Bight of the North Sea has been intensively studied. The first intensive campaigns performed by Gilson (1900) gave an insight on the faunal diversity of the Belgian coasts but it is only since the early seventies that various researchers described the benthic communities of that region (Heip & Decraemer, 1974; Jensen, 1976; Govaere et al., 1980; Vincx, 1981). Focussing respectively on the macro and meiobenthos, Vanosmael et al. (1982) and Willems et al. (1982) stressed the ecological value of the Belgian Continental Shelf (BCS) sandbanks, Southwest – Northeast oriented. They suggested that those banks act as possible islands and generate a range of habitats for marine fauna. More recently, Beyst et al. (2001) listed the species of the surf zone occurring on Belgian sandy beaches and raised the question of their nursery function. Dewicke et al. (2003) emphasized an onshore–offshore gradient in the density and biomass of the hyperbenthos, here defined as the small animals living close to the sea bed. In 2004, Van Hoey et al. summarized the large-scale spatial distribution of the macrobenthos of the BCS by combining a large amount of data collected from 1994 to 2000. All these researches directly concern the benthic fauna of soft bottoms. Despite the studies of Daro (1969, 1970), De Pauw & Van Damme (1992) and Volckaert et al. (2002) on the faunal and floral assemblage of intertidal structures along the coast, there is a paucity of available data devoted to communities of hard substrata on the BCS. This lack of information is a consequence of hydrodynamism schemes. Indeed fine sediments dominate the Southern part of the North Sea due to a hydrodynamism decrease after the Dover Strait (Prygiel et al., 1988) while epifauna associated with pebbles is still well represented in the Strait (Davoult, 1990).

Assuming that *Asterias rubens* mainly feeds on molluscs (*Mytilus edulis* L.) that need hard substrata to develop (Castilla & Crisp, 1973), the findings of this echinoderm could indirectly reveal the presence of hard substrata. Only a few limited places where concentrations of the starfish *A. rubens* occur on the BCS were documented by De Clerck et al. (1973, 1974a, b, 1975) and therefore could be assigned to hard substrate regions. Moreover, Maertens (1989) and Deleu (2002) confirmed the presence of such regions on the BCS but so far studies on the fauna of these areas have never been performed (Kerckhof & Houziaux, 2003). Finally, Degraer (1999) and Van Hoey et al. (2004) mention a very special macrobenthic community with high density of the Bivalve *Barnea candida* (L.) in outcropping tertiary clay layers near Oostende. As a consequence, the question of epifaunal assemblages on hard substrata for the Belgian waters has been hardly addressed. Although unnatural, shipwrecks represent another type of hard substrate and more than 200 recent shipwrecks which are a potential threat to navigation or fisheries are recorded along the Belgian coast (Norro, pers. communication). Moreover, it has been recently estimated that 10 000 wrecks lie in the Dutch sector of the North Sea (Leewis et al., 2000). Theses structures represent substrata available for the colonization of subtidal sessile epibenthic communities in Belgian coastal waters. Even if the fauna living on these structures could be regarded as exotic, shipwrecks represent nevertheless a part of the habitat diversity that cannot be neglected. Technical problems are certainly the main reason why the fauna of shipwrecks have scarcely been studied (Massin et al., 2002). This fauna has been prospected along the Dutch Continental Shelf (Leewis et al., 2000) and on a single shipwreck near the Isle of Lundy (Bristol Channel, England; Hiscock, 1980) but this has never been done for the BCS. This paper presents the first results of a detailed study aiming to understand the possible role of such structures in the biological diversity of the Southern Bight of the North Sea. These preliminary results present a first estimation of the fauna of two shipwrecks from the BCS with a distinction between horizontal and vertical surfaces in order to determine whether different associations could be due to sedimentation. We intend to describe the basic features of the dominant communities found on shipwrecks with emphasis on some species of special interest.

Material and method

The macrofauna (fauna retained on a 1 mm sieve) of two BCS shipwrecks was investigated from July to the beginning of September during the years 2001 and 2002 on board of the A.962 'RV Belgica.' These two shipwrecks were chosen according to the following criteria: (i) large size thus ease of location, (ii) good state allowing safe working conditions, (iii) location out of navigation roads, and (iv) sunk for at least 10 years to reach a mature community (Leewis et al., 2000). The first shipwreck investigated was the Birkenfels, 156 m long, 42 m depth, sunk in 1966 and lying 30 nautical miles from the coast (WGS-84 coordinates: N 51°38′,989 – E 02°32′,268). The second one was the Bourrasque, 106 m long, 16 m depth, sunk in 1940 and lying 8 nautical miles from the coast (WGS-84 coordinates: N 51°14′,964 – E 02°33′,026). The Birkenfels is located in open sea conditions with a maximum current speed during neap and spring tides of 0.9 and 1.7 knots, respectively. The Bourrasque lies between the Buiten Ratel sandbank and the Kwintebank close to the shore. The maximum current speeds during neap and spring tides are 0.8 and 1.3 knots, respectively. These two wrecks lie in different water conditions according to the distance from the coast, since the BCS displays a gradient from turbid, nutrient rich and well-mixed inshore waters towards more oceanic, less turbid and less productive offshore waters (Cattrijsse & Vincx, 2001). Figure 1 shows the location of the two chosen shipwrecks among the other wrecks of the BCS.

Teams of three divers sampled vertical and horizontal oriented surfaces in order to document the possible faunal differences due to sedimentation process. During a tidal cycle (≅12 h), currents turn around wrecks so that all external surfaces are exposed. Due to the large size of the wrecks and the

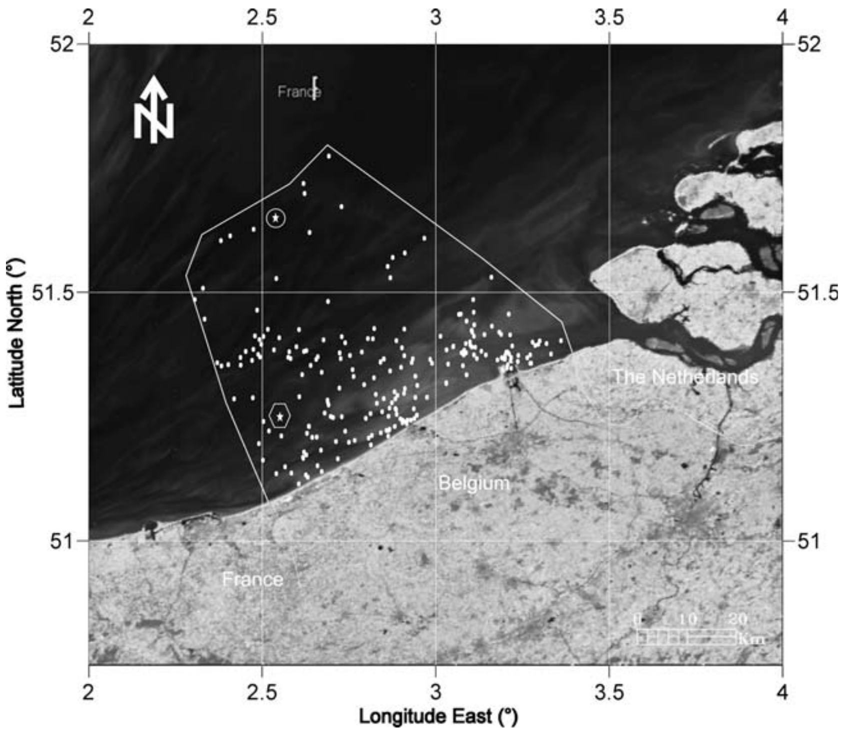

Figure 1. Location of the 231 inventoried wrecks of the Belgian Continental Shelf. The shipwreck of the Birkenfels is outlined by a circle; the shipwreck of the Bourrasque by a hexagon. Coordinates are WGS-84. Source: Afdeling Waterwegen Kust (AWK), Belgium. Map background by Image courtesy of MODIS Rapid Response Project at NASA/GSFC.

poor underwater visibility (1–4 m), it was impossible to sample the same locations twice; therefore, all the sampling spots must be considered as differently exposed areas. As a consequence, on these exposed surfaces the most important factor for the settlement of sessile epifauna should be governed by the orientation (horizontal/vertical) of surfaces to the current. A total of 7 samples has been taken on each shipwreck (Table 1) representing a total surface of 0.875 m^2.

Sampling of protected surfaces such as overhangs and more sheltered areas inside the shipwrecks was not undertaken. Moreover, abiotic parameters being quite similar for all collection times (July and September 2001, 2002), it is assumed that no seasonal or annual effects influence the observed variations in fauna.

A three step procedure was adopted in order to assess the macrofauna of the shipwrecks. First, each team randomly placed a 50 × 50 cm frame on a vertical or horizontal surface and digital pictures of the frame were taken. Then, a *de-visu* inventory of the dominant visible species was performed within the 50 × 50 cm frame. Finally, a subsurface of 25 × 25 cm was scraped and transferred into plastic bags for further analysis. Divers also identified fish and jellyfish around the shipwrecks but these were not included in the analysis although they are listed for the reader's information.

On board, animals were relaxed in 3.5% $MgCl_2$ solution for two hours and then transferred to buffered formalin solution (final concentration 4%, pH 8.2–8.4). Later on, specimens were transferred to 70% buffered alcohol for permanent storage. The samples were then sorted and species counted and identified to the lowest possible taxonomic level. All the collected material is deposited in the collections of the Royal Belgian Institute of Natural Sciences under the IG number 29462. Additional species were identified by examination of digital pictures. Colonies of taxa such as Hydrozoans or Bryozoans were each counted as one individual.

Species richness was estimated through species accumulation curves based on two non-parametric estimators: the Jack2 estimator (Burnham & Overton, 1978, 1979) and ACE (Abundance based

Table 1. Date, depth and orientation of the samplings

Bourrasque			Birkenfels		
Date	Depth (m)	Orientation	Date	Depth (m)	Orientation
04/07/02	17.8	Horizontal	11/07/01	29	Horizontal
04/07/02	17.8	Vertical	11/07/01	27	Horizontal
05/07/02	20.0	Vertical	11/07/01	22	Horizontal
05/07/02	18.4	Horizontal	04/09/02	23	Horizontal
05/07/02	20.0	Vertical	04/09/02	23	Vertical
05/07/02	18.0	Vertical	04/09/02	23	Vertical
05/07/02	20.0	Horizontal	04/09/02	23	Vertical

Coverage Estimator) (Chazdon et al., 1998). ACE is a modified version of the Chao2 estimator developed by Chao & Lee (1992) that takes into account the overestimation in species richness of the Chao2, especially when a small number of samples is used. The estimates were computed with EstimateS using 100 randomizations without replacement (Colwell, 1997). The sample's diversity was described using Hill numbers N_0, N_1, N_2 and N_∞. N_0 is the species richness, N_1 the exponential Shannon–Wiener index, N_2 the reciprocal of Simpson's index and N_∞ the reciprocal of the proportional abundance of the most common species (reciprocal of Berger–Parker index) (Hill, 1973).

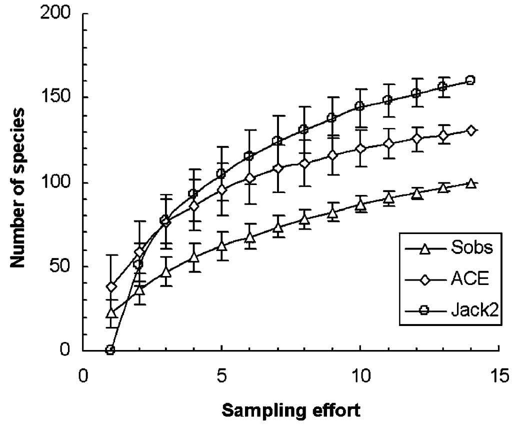

Figure 2. Species accumulation curves. Estimators of the species richness are the total number of observed species (Sobs), the Abundance based Coverage Estimator (ACE) and the Jacknife 2 Estimator of true richness (Jack2). Plotted values are mean ± SD of 100 estimates based on 100 randomization.

Results

Species richness, abundance and diversity

The total number of taxa identified is 121 (see Table A in Appendix). Among them 22 were identified *de-visu* by divers: three Scyphozoans, two Actinarians, one Hydrozoan, three Opisthobranchia, two Decapoda and 11 species of fish. The other 99 taxa were identified from the scraped surface, with 65 and 74 taxa for the Birkenfels and Bourrasque, respectively. Estimates of cumulative species richness against sampling effort showed no sign of approaching asymptotic values (Fig. 2). Nearly 100 species were observed while the estimated number of species for ACE and Jack2 are respectively 131 and 160. Fitting a log regression on the number of species ($R^2 \geq 0.99$), predicted values for 100 samples are respectively 156 for Sobs, 205 for Jack2 and 280 for ACE.

The mean, minimum and maximum number of species for the shipwrecks is presented in Table 2. The number and density of species for both shipwrecks are similar with more variation among samples for the Bourrasque. The huge mean and standard error for the density is due to a single species, the tube-dwelling amphipod *Jassa herdmani* (Walker). Its density ranges from 100 to 101,120 ind/m^2.

Figure 3 shows the rank/abundance graph by shipwreck. Both are dominated by a small number of species with many 'rare' species. The dominance of *J. herdmani* reaches 76% when all samples are pooled together. Table 3 shows the cumulative dominance for pooled samples when *J. herdmani* is excluded: 81% of the dominance is due to the 10 most abundant species. The most represented

Table 2. Number of species (N_0) and density on the two shipwrecks samples (25 × 25 cm)

Shipwreck	N_0	Density (ind/m^2)
Birkenfels		
Mean	25 ± 5	18 460 ± 28 930
Min	18	3950
Max	33	77 056
Bourrasque		
Mean	19 ± 11	20 300 ± 43 810
Min	11	1870
Max	41	119 540

Mean is expressed with it standard error.

phyla in terms of species diversity for both shipwrecks are Polychaets, Crustaceans, Molluscs and Cnidarians (Table 4). Less than 50% of the species are common to both wrecks (Table 5). The Spearman rank correlation between species richness (N_0) of samples and the other Hill numbers (N_1, N_2 and N_∞) is not significant ($p > 0.05$) (Table 6). The low value for the dominance index indicates a high degree of unevenness but this does not hamper high species richness. On the contrary, the samples containing most species (sample 4 and 14, with 33 and 41 species, respectively) have low values for the N_1, N_2 and N_∞. A dense mat of a

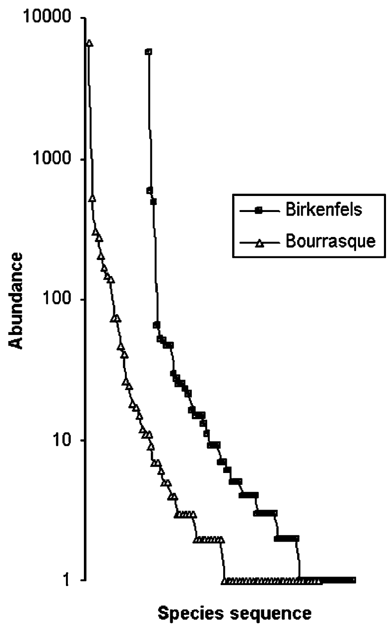

Figure 3. Rank abundance plot for the onshore (Bourrasque) and offshore (Birkenfels) shipwrecks.

Table 3. Main dominant species of the complete dataset

Species	Dominance (%)	Cumulative dominance (%)
Pisidia longicornis	19.1	19.1
Phtisica marina	13.8	32.9
Ophiotrix fragilis	12.6	45.6
Phyllodoce mucosa	8.2	53.8
Lanice conchilega	8.2	61.9
Diadumene cincta	6.3	68.2
Metridium senile	4.8	73.1
Balanus crenatus	3.5	76.6
Stenothoe valida	2.6	79.3
Eumida sanguinea	1.9	81.2

Colonial species (Hydrozoa and Bryozoa) and the amphipod *Jassa herdmani* are excluded.

Table 4. Distribution of the organisms among taxonomic groups for both shipwrecks (nr: not represented)

Phylum	Birkenfels (%)	Bourrasque (%)
Polychaeta	33.3	37.8
Crustacea	21.2	21.6
Mollusca	19.7	13.5
Cnidaria	9.1	17.6
Echinodermata	6.1	4.1
Bryozoa	4.5	2.7
Nemertina	1.5	nr
Porifera	1.5	1.4
Sipunculia	1.5	1.4
Tunicata	1.5	nr

Table 5. Shared species based on taxonomic groups by the two shipwrecks

Phylum	Number of species		% shared
	Birkenfels	Bourrasque	
Sipunculia	1	1	100
Mollusca	13	10	53
Crustacea	14	16	43
Echinodermata	4	3	40
Polychaeta	22	28	39
Cnidaria	6	13	36
Bryozoa	3	2	25
Nemertina	1	0	0
Porifera	2	1	0
Tunicata	1	0	0

Table 6. Hill numbers values for the 14 samples with indication on the orientation of the sampling surface. N_0 is the species richness, N_1 the exponential Shannon-Wiener index, N_2 the reciprocal of Simpson's index and N_∞ the reciprocal of the proportional abundance of the commonest species (reciprocal of Berger-Parker index)

	N_0	N_1	N_2	N_∞
Birkenfels				
Horizontal	11	4.23	3.10	2.00
	15	6.22	4.18	2.30
	21	7.59	5.27	3.16
	23	4.63	2.14	1.47
Vertical	11	5.43	4.04	2.66
	13	5.59	4.00	2.58
	41	2.14	1.39	1.18
Bourrasque				
Horizontal	18	2.01	1.43	1.21
	23	5.00	2.85	1.77
	25	10.07	6.51	3.15
	33	1.37	1.10	1.05
vertical	22	5.27	3.80	2.79
	28	6.08	3.97	2.50
	28	8.58	5.91	3.69

Hydrozoan species, *Tubularia indivisa* L. is the common feature of these two samples. The erect perisarc of this species, which can reach 15–20 cm long, creates a third dimension onto the two-dimensional shipwreck surface.

Faunal assemblage description

We observed two main communities on both shipwrecks. The first one is dominated by the hydrozoan *Tubularia indivisa* associated with *Jassa herdmani* (Amphipoda). The second one is dominated by *Metridium senile* (L.) (Anthozoa). Cnidarians are the dominant phylum represented particularly by three very abundant species: *T. indivisa* (Hydrozoa), *M. senile* (Anthozoa) and *Diadumene cincta* Stephenson (Anthozoa). *T. indivisa* is always associated with *Jassa herdmani*. This amphipod builds a tube made of sediment that aggregates around the perisarc and sometimes even completely covers it. Samples with a high species diversity are, as previously mentioned, linked to an important development of *T. indivisa* colonies. One can assume that the perisarc acts as a new colonization surface for a wide range of animals. On the contrary, concentration of *M. senile* does not permit the development of other species and therefore surfaces where *M. senile* is dominant are characterized by very few species.

At the prospected depth there was no algal development. The animal community was dominated by carnivores/scavengers and passive suspension-feeders. For the active suspension-feeders, only a few bivalve species were found as juveniles and in low densities; moreover, only three species of sponges and one tunicate were identified, all in low densities. The ophiuroid *Ophiotrix fragilis* (Abildgaard) is mainly found offshore on the Birkenfels where it can form dense aggregations up to 2000 ind/m^2. The Serpulid *Pomatoceros triqueter* (L.) covers the metal sheet of that shipwreck while *Balanus crenatus* Bruguiére is found on all onshore samples (Bourrasque). *Phyllodoce mucosa* (Oersted) occurred at a density ranging between 16 to 900 ind/m^2 on the Birkenfels and between 160 to 1680 ind/m^2 on the Bourrasque. The Anomuran crab *Pisidia longicornis* (L.) is common at both sites, being represented by juveniles with densities ranging between 32 to 4860 ind/m^2. Only juveniles of *Psammechinus miliaris* (Gmelin) were found (maximum test length of 10 mm). Differences between the faunal associations on vertical and horizontal surfaces were observed. Sedimentation on horizontal surface favors some soft sediment species. On these surfaces tubes of the Polychaeta *Lanice conchilega* (Pallas) were observed at a maximum density of 3680 ind/m^2. *Nassarius incrassatus* (Ström) was only found on horizontal surface of the Birkenfels. The Polychaet *Phyllodoce mucosa* was preferentially found on horizontal surfaces.

The mollusc *Epitonium clathratulum* (Kanmacher) has been found in densities ranging from 32 to 144 ind/m^2 on horizontal surfaces on both shipwrecks but more frequently on the Birkenfels. The Poriferan *Dysidea fragilis* (Montagu) is recorded for the first time in Belgian waters.

Discussion

In this study the total sampled area on both shipwrecks only represents 0.875 m^2, nevertheless 65 and 74 macrofauna species have already been identified on the offshore and onshore sites respectively. The species accumulation curves indicate that more intensive sampling will certainly add more species to the list. With only two shipwrecks and 14 samples we already reached the species richness mentioned by Leewis et al. (2000) (127 species) for a 5 year study covering 21 Dutch shipwrecks. The low species richness observed by Leewis et al. (2000) might be related to the fact that the sampling was mainly made by *de-visu* methods with a potential information loss on small macrofauna species. On the other hand, Hiscock (1980) identified a total of 187 taxa on a 1.4 m^2 horizontal surface of a shipwreck from the isle of Lundy (SW of England) sunk 5 years previously. The expected species richness of the two shipwrecks prospected in the present study is closer to the value given by Hiscock (1980). Cattrijse & Vincx (2001) reviewed the Belgian data on macrobenthos for soft bottoms and found that species richness for a site varied from 4 to 33 and that species richness for a zone (sites pooled for 9 defined zones on the BCS) ranged from 19 to 87. Comparison with our data indicates that average macrobenthos biodiversity on the BCS is at least ten times higher on hard substrata than on soft substrata.

The pebble communities in the Dover Straits have a pooled species diversity of 211 species for the coastal zone and 128 species for the offshore zone (Davoult, 1990). The observed faunal assemblage on shipwrecks shows some resemblance to sites subjected to high hydrodynamics in the Dover Strait. In this community, epifauna is the dominant group of organisms. Four dominant species are common to pebble communities and studied shipwrecks: *Ophiotrix fragilis*, *Pisidia longicornis*, *Lepidonotus squamatus* (L.) and *Psammechinus miliaris*. On the contrary, pebble communities are not dominated by Hydrozoan and Anthozoan species.

The absence of macro algal development at the studied depth is probably due to the low light intensity reaching the wrecks. The animal community is dominated by carnivores/scavengers and passive suspension-feeders and only very few active suspension-feeding species were observed. This situation can be compared with what has been described on hard substrata in the Oosterschelde (SW Netherlands). Leewis & Waardenburg (1990) studied the faunal assemblages after the construction of a storm surge barrier in the mouth of the Oosterschelde estuary. They found that *Metridium senile* and *Tubularia indivisa* communities dominate the area close to the dam, where the current velocity is the strongest. Away from the dam, under low current conditions, communities with Porifera and Tunicata develop. Indeed, these active filter-feeders are more competitive when the current velocity is low (de Kluijver & Leewis, 1994). In another study in the Adriatic Sea (Italy, Mediterranean Sea) a community on outcrops and shipwrecks in low current conditions was also dominated by active suspension filter-feeders: Tunicata, Bivalvia and Porifera accounted for 55% of the species diversity while passive suspension filter-feeders represented only 10% of the species (Gabriele et al., 1999). It is likely that the more sheltered parts of the shipwrecks (mainly inside the shipwrecks themselves) might harbor active suspension filter-feeders but this part of the shipwrecks has not been investigated so far. In both shipwrecks, the amphipod *Jassa herdmani* was found in huge densities up to 100 000 ind/m^2. They inhabit self-constructed tubes from which they extend the anterior half of their bodies to gather detritus and filter suspended particles and plankton (Conlan, 1989). The construction of these tubes prevents them from being washed out by strong currents (Ulrich et al., 1995). They are known as important fouling organisms. This species seems to out-compete most of the other amphipods that are represented by three species of the genus *Stenothoe* and five species of Caprellidea. The members of the genus *Stenothoe* are filter-feeders (Barnard, 1969) and some are known to live on Hydrozoa ramifications (Lewis, 1992). Caprellidea are mainly filter-feeders but some species adopt a scraping feeding strategy (Guerra-Garcia, 2002). Our results indicated that poor species assemblages are associated with the huge development of the Anthozoan *M. senile* in some places; a phenomenon already described by de Kluijver & Leewis (1994). One possible reason is the asexual mode of reproduction of this anthozoan by basal laceration (Manuel, 1981) that tends to overgrow other organisms (Bucklin, 1987). Another reason could be toxin production (Anderluh & Macek, 2002) and exudation preventing larval settlement (Koh, 1997).

The hard substrata provide attachment sites and microhabitats for a range of species typically not found in the surrounding soft sediments. As with other artificial structures, shipwrecks raise the question of the 'attraction versus production' debate (see among others Bohnsack et al., 1997; Pickering & Whitmarsh, 1997; Bortone, 1998; Page et al., 1999; Hall et al., 2000; Jensen et al., 2000). Although not quantified, the increased density of fish around the shipwreck was probably important since 11 species were encountered; among them, the commercially important species *Gadus morhua* L.

Finally, some species have to be considered as having conservation value because of their scarcity or rareness. Several living specimens of the amphipod *Caprella tuberculata* Guérin were found on the Birkenfels. This species does not seem to be uncommon but is scarce along the British coasts (Isaac et al., 1990) and has been mentioned only very recently for the Belgian marine fauna (Massin et al., 2002). *Epitonium clathratulum* is a rare species for the Belgian marine fauna; it was only known from a few stranded specimens (Balckeljau, 1986; Vanhaelen, 1989) and one single living specimen collected on a breakwater (Jonckheere, 2001). In the Netherlands, the first record of a living specimen was made by Eisma (1966) and more recently it was found in the Osterschelde (The Netherlands) (Wetsteyn & Nieuwenhuize, 1996). During the present study, *E. clathratulum* was observed on both shipwrecks, the species being more frequent on the Birkenfels. *E. clathratulum* was found only on horizontal surfaces were a thin layer of sediment occurs. This observation highlights the importance of sedimentation on horizontal surfaces that seems to favour some soft sediment molluscs and polychaeta species such as *Lanice conchilega*. The Epitonidae are carnivorous and known to feed on Anthozoa (Graham, 1988). But compared to other horizontal samples, relatively few Anthozoa (*M. senile* and *D. cincta*) were present in the samples where *E. clathratulum* was found. The Poriferan *Dysidea fragilis* is recorded for the first time in the Belgian waters. This species is widespread but seldom dominant in the British Isles and can be found along the Atlantic coast of Europe and in the Mediterranean Sea (Ackers et al., 1992).

As a conclusion, these preliminary results emphasize spots of high species richness for the sessile and slow moving epifauna. The two investigated sites show striking differences in terms of species assemblage but more intensive sampling is needed in order to discern ecological patterns. The possible role of such 'hard substrata islands' in an environment dominated by soft bottom sediments needs further research in order to evaluate their impact on the reproduction, dissemination and protection of North Sea species. In this respect, two separate questions need to be addressed. First, what is the origin of the species present on shipwrecks in the Belgian waters? Second, do shipwrecks allow these species to develop, reproduce and disseminate? We do not know anything about natural hard substrata available on the BCS for the colonization of subtidal epifauna. It seems that if present, they occur in very localized and limited areas. A comparison between the fauna encountered on these natural and unnatural outcrops could be helpful in order to know if shipwrecks are discrete spots where a natural fauna occurs or if shipwrecks play an important role for the dissemination of some species that would otherwise not be present. In this later case, shipwrecks, even if hotspots for diversity, could favor the dissemination of possibly harmful exotic species and act as stepping-stones to put in touch different populations of a single species. This could lead to a loss of genetic diversity and fitness for all or part of these populations.

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Appendix

Table A. List of species found only in the Birkenfels, Bourrasque and common to both shipwrecks. Species designated by 'photo' were not collected but identified by mean of digital pictures. Species designated by * were identified in situ by divers. The taxonomy is based on the 'European Register of Marine Species' (Costello et al., 2001)

		Birkenfels specific taxa	Bourrasque specific taxa	Common taxa to both shipwrecks
PORIFERA		*Dysidea fragilis* (Montagu, 1818)	*Haliclona* sp.	
		Halichondria cfr panicea (Pallas, 1766)		
CNIDARIA	Hydrozoa		*Bougainvillia muscus* (Allman, 1863)	*Hydractinia echinata* (Flemming, 1828)
			Campanularia volubilis (Linnaeus, 1758)	*Obelia bidentata* Clarke, 1875
			Clytia gracilis (Sars, 1850)	*Sarsia eximia* (Allman, 1859)
			Clytia hemisphaerica (Linnaeus, 1767)	*Tubularia indivisa* Linnaeus, 1758
			Hydrallmania falcata (Linnaeus, 1758)	
			Laomedea flexuosa Alder 1857	
			Nemertesia antennina (Linnaeus, 1758)	
			Obelia dichotoma (Linnaeus, 1758)	
			Sertularia cupressina Linnaeus, 1758	
			Tubularia larynx Ellis & Solander, 1786	
	Schyphozoa	*Aequorea vitrina* Gosse, 1853*		*Cyanea lamarcki* Péron & Lesueur,1810*
		Chrysaora hysoscella (Linnaeus, 1767)*		
	Anthozoa	*Alcyonium digitatum* Linnaeus, 1758	*Sagartia* sp.*	*Diadumene cincta* Stephenson, 1925
		Anemonia sp. (photo)		*Metridium senile* (Linnaeus, 1767)
		Sagartia sp. (photo)		*Sagartia troglodytes* (Price *in* Johnston, 1847)
		Urticina felina (Linnaeus, 1767) (photo)		
NEMERTA		Nemertinea spp.		
ANNELIDA	Polychaeta	*Alentia gelatinosa* (M. Sars, 1835)	Pectinariidae	*Autolytus* sp.
		Eulalia cfr fucescens de Saint Joseph, 1888	*Cirratulus filiformis* Keferstein, 1862	*Eumida sanguinea* (Oersted, 1843)
		Nereis zonata Malmgren, 1867	*Eteone picta Quatrefages, 1865*	*Eupolymnia nesidensis* (Delle Chiaje, 1828)
		Poecilochaetus serpens Allen, 1904	*Eulalia* spp.	*Eusyllis blomdstrandi* Malmgren, 1867
		Procerastea halleziana Mallaquin, 1893	*Eulalia viridis* (Linnaeus, 1768)	*Harmothoe extenuata* (Grube, 1840)
		Syllis armillaris (O.F. Müller, 1776)	*Gattyana cirrhosa* (Pallas, 1766)	*Harmothoe* spp.
		Thelepus cincinnatus (Fabricius, 1780)	*Nereimyra punctata* (O.F. Müller, 1788	*Kefersteinia cirrata* (Keferstein, 1862)
			Nicomache sp.	*Lanice conchilega* (Pallas, 1766)
			Ophelia sp.	*Lepidonotus squamatus* (Linnaeus, 1758)
			Phyllodoce mucosa (Linnaeus, 1767)	*Nereis pelagica* Linnaeus, 1758
			Phyllodoce spp.	*Nereis* sp.

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Table A. (Continued)

		Birkenfels specific taxa	Bourrasque specific taxa	Common taxa to both shipwrecks
			Polydora sp.	*Pomatoceros triqueter* (Linnaeus, 1758)
			Sabellaria spinulosa Leuckart, 1849	*Phyllodoce mucosa* (Öersted, 1843)
			Scoloplos armiger (O.F. Müller, 1776)	*Procerastea perieri* Gravier, 1900
			Thelepus setosus (Quatrefages, 1865)	*Syllis gracilis* Grube, 1840
MOLLUSCA	Bivalvia	*Heteranomia squamula* (Linnaeus, 1758)		*Aequipecten opercularis* (Linnaeus, 1758)
		Venerupis geographica (Gmelin, 1791)		*Mytilus edulis* Linnaeus, 1758
				Mysella bidentata (Montagu, 1803)
	Gasteropoda	*Archidoris pseudoargus* (Rapp, 1827)	*Cuthona* sp.	Aeolidiidae
		Coryphella verrucosa (M. Sars, 1829)	*Nassarius reticulatus* (Linneaus, 1758)	*Crepidula fornicata* (Linnaeus, 1758)
		Dendronotus frondosus (Ascanius, 1774)		*Epitonium clathratulum* (Kanmacher, 1798)
		Euspira pulchella (Risso, 1826)		*Eubranchus* sp.
		Flabellinidae sp. (photo)		Rissoidae
		Nassarius incrassatus (Ström, 1768)		
SIPUNCULIA				*Sipunculus* sp.
CRUSTACEA	Decapoda	*Hias araneus* (Linneaus, 1758)		*Cancer pagurus* Linneaus, 1758
		Macropodia rostrata (Linnaeus, 1761)		*Liocarcinus holstatus* (Fabricius, 1798)
		Paguridae		*Liocarcinus* sp.
				Necora puber (Linnaeus, 1767)*
				Pagurus berhnardus (Linnaeus, 1758)
				Pilumnus hirtellus (Linnaeus, 1761)
				Pisidia longicornis (Linneaus, 1767)
	Amphipoda	*Caprella tuberculata* Guérin, 1836	*Pseudoprotella phasma* (Montagu, 1804)	*Caprella linearis* (Linnaeus, 1767)
			Pariambus typicus (Kroyer, 1844)	*Jassa herdmani* (Walker, 1893)
			Stenothoe marina (Bate, 1856)	*Phtisica marina* Slabber, 1769
			Stenothoe sp.	*Stenothoe monoculoides* (Montagu, 1815)
				Stenothoe valida Dana, 1855
	Cirripedia		*Balanus crenatus* Bruguiére, 1789	
	Cumacea		Cumacea	
	Copepoda		Copepoda	
BRYOZOA		*Disporella hispida* (Fleming, 1828)	*Conopeum seurati* (Canu, 1928)	*Electra pilosa* (Linnaeus, 1767)
ECHINODERMATA	Asteroidea	*Asterias rubens* Linnaeus, 1758		
	Echinoidea		Clypeasteroidea	*Psammechinus miliaris* (Gmelin, 1778)
	Ophiuroidea	*Ophiura albida* Forbes, 1839		*Ophiotrix fragilis* (Abildgaard, 1789)

TUNICATA	*Molgula cfr occulta* Kupffer, 1875		
PISCES	*Gadus morhua* Linnaeus, 1758*	*Dicentrarchus labrax* (Linnaeus, 1758)*	*Pollachius virens* (Linnaeus, 1758)*
	Pollachius pollachius (Linnaeus, 1758)*	*Myoxocephalus scorpius* (Linnaeus, 1758)*	*Pomatoschistus* sp. (photo)*
	Scomber scombrus Linnaeus, 1758*	*Parablennius gattorugine* (Linnaeus, 1758)*	
	Trisopterus luscus (Linnaeus, 1758)*		
	Trisopterus minutus (Linnaeus, 1758)*		
	Trachurus trachurus (Linnaeus, 1758)*		