SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

SPSD II

BELGIAN SHIPWRECK : HOTSPOTS FOR MARINE BIODIVERSITY (BEWREMABI)

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PART 2

GLOBAL CHANGE, ECOSYSTEMS AND BIODIVERSITY

ATMOSPHERE AND CLIMATE

MARINE ECOSYSTEMS AND BIODIVERSITY

TERRESTRIAL ECOSYSTEMS AND BIODIVERSITY

NORTH SEA

ANTARCTICA

BIODIVERSITY

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Part 2:
Global change, Ecosystems and Biodiversity

FINAL REPORT

Belgian shipwreck : hotspots for marine biodiversity
BEWREMABI

EV/42

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Abstract

The seabed of the Belgian part of the Southern Bight of the North Sea is mostly composed of sandy soft sediments. Natural hard substrates like pebbles are rare and only occur locally. The majority of the hard substrate is artificial: man made constructions and shipwrecks. For the first time the fauna of these artificial reefs have been studied by divers. Ten shipwrecks located on the Belgian Continental Shelf (BCS) at different distance from off the coast have been prospected. During this research program the diversity as well as spatial and temporal variations in community structure were analysed.

A total of 224 macrospecies (> 1 mm long) have been identified on shipwrecks, with 46 species new to the Belgian fauna. No algae have been observed. Moreover, several species said to be rare to the Belgian marine fauna are abundant on shipwrecks. All shipwrecks are strongly dominated by cnidarians in terms of biomass and by crutaceans (mainly amphipods) in terms of abundance (maximal density up to 445.800 ind/m^2). On average, 70% of the hard substrate provided by shipwrecks is covered by the epifauna. The artificial hard substrate communities isolate strongly from the surrounding soft sediment communities by sharing few species (only 9.6%), being dominated by different faunal groups (mainly crustaceans, polychaetes and molluscs) and having a distinct trophic organization. Looking at a cross-shore gradient of sites, and taking into account biotic and abiotic parameters, three groups of shipwrecks could be determined. *Metridium senile*, a sea anemone dominates a species poor community of the coastal sites. Channel water masses influence the offshore sites causing a more stable abiotic environment. The hydrozoan *Tubularia indivisa* dominates this community. Intermediate sites are also dominated by *T. indivisa*, but a higher biomass is here observed. It also appears that this *T. indivisa* is a key species allowing for the settlement of a large set of secondary epibionts. In term of epifauna biomass, the shipwrecks are much richer than the surrounding sediment (on average 628 g AFDW. m^{-2} versus 10 g AFDW. m^{-2}).

The meiofaunal communities studied on two shipwrecks from the BCS are characterised by a high abundance of both nematodes and amphipods. If compared with soft bottom communities, several new genera of nematodes are present. Meiofauna is also characterised by the high importance of epistrate and selective deposit feeders, and by the presence of giant nematodes. Shipwreck influence on the fauna present in the surrounding is significant and strongly dependent on the shipwrecks. Some communities (i.e. *Abra alba*) benefit from the absence of trawling close to the shipwrecks.

Results from this project have been disseminated through several channels : papers in international journals, communications to congress, databases, a web site is available. Information collected during the project have been used to elaborate a brochure on wreck biodiversity in order to increase public awareness of the importance of marine biodiversity. In the same context, an illustrated book describing the most important species is in preparation. The work achieved during this project will be usefull in order to establish a set of standard protocols adapted to monitor biodiversity of hard substrates of the North Sea, such as shipwrecks and the constructions of windmill farms.

Key words : Shipwrecks – North Sea – Biodiversity – Scientific diving

1. Introduction and objectives

Southern North Sea abiotic environment

The North Sea formed 240 million years ago but the actual form of the basin resulted from several ice ages events occurring in the last 2 million years. The North Sea is defined as a young ecosystem developed during the past 10,000-20,000 years. Its general circulation shows a cyclonic gyre pattern in the central North Sea where water enters by the channel to move northward while Atlantic water enters the North Sea by the North of the British island moving toward the South East. Atlantic and channel waters flows through the Skagerrak (North of Denmark) and leave the North Sea by the Norwegian current (EFEP, 2002).The Southern North Sea bathing Belgian water i.e. the Belgian Continental Shelf (BCS) is a highly dynamical environment dominated by strong tides. Difference between high tide and low tide elevations can reach 4 m. Tide induces strong currents on the continental shelf and speed of the current can reach and sometime exceed 1 m/s. This effect stirs the water body resulting in, most of the time, a vertically well mixed water column.

State of the art

Biodiversity of Belgian marine benthos is well documented for the meiobenthos and the small macrobenthos (up to a few mm long) from soft bottoms (see Cattrijsse & Vincx 2001 for an extensive literature review). The collection of samples in these studies were done with Van Veen grab, a sampling gear that is not designed to study epibenthos of hard subtratum. Large epibenthos and sessile fauna have been collected since more than a century (Gilson 1900) and more recently by the Sea Fisheries Departement (Oostend). They focused their attention mainly on commercially important species (*Crangon crangon*, Pleuronectidae, Soleidae, Gadidae, Clupeidae) and occasionally on by-catches (Hydrozoa, Anthozoa, Annelida, Bryozoa, Crustacea, Mollusca and Echinodermata) (sea among others De Clerck *et al.,*1973, 1974a, 1974b, 1975). Samples were either collected by means of different trawls or by Van Veen grab. Most of their results were published in "grey" literature.

Since Gilson (1900), several collecting methods for the study of marine benthic biodiversity have been used; they all have in common that they are operated remotely, from the sea surface: Van Veen grabs, box corers, trawls and sledges. These methods may be sufficient to give an overview of the soft bottom benthic fauna on the BCS, but are totally inappropriate or result in underestimation for hard bottoms (rocks and shipwrecks) and particularly for sessile fauna. Cattrijsse & Vincx (2001) emphasise this scarcity of data on sessile epifauna. Only four studies (Daro 1969, 1970; De Pauw & Van Damme 1992; and Engledow et al 2002, Van Hoey *et al.,*2004) dealing with intertidal fauna of artificial hard substrates studied at low tide, are known.

Approach, by direct observation and sampling by S.C.U.B.A., seems to be essential to study biodiversity of shipwrecks and hence to have a better knowledge of the total biodiversity of the BCS. The proposed program entitled BEWREMABI (BElgian ShipWREck: hotspot for MArine BIodiversity) is perfectly in accordance with the Jakarta Mandate, a consensus on the importance of marine and coastal biological diversity.

Shipwrecks prevent soft-substrate ecosystems from being disturbed by beam trawl fisheries and alter the local hydrodynamy and sedimentology. This may impact the soft-substrate benthic fauna in several ways. The absence of beam trawling will directly allow soft-substrate epifauna to fully develop. Furthermore, shipwrecks create hydrodynamically benign conditions, which may favour fragile epibenthic species. These epibenthic species largely contribute to the habitat complexity of soft substrates nearby shipwrecks and, as a consequence of this increase in habitat complexity, a suit of epifauna-associated benthic species may indirectly colonise the area.

It is known that large biogenic structures lying on the seafloor, such as coral fragments, house a typical associated meio-epifaunal community. It was found that several taxa (on different taxonomic levels) have clear morphological adaptations that enable them to attach themselves to these structures and use them as suitable substrates for feeding and moving without being washed away by the currents on these relatively unprotected surfaces. Small-scale structural differences between substrates (e.g. between the complex, three-dimensional sponge spicule framework and the rough surface of a branched coral skeleton) have an important effect on the community composition and may require even more specific morphological adaptations. On the other hand, sessile filter- and suspension feeders may take advantage of the elevation created by the biogenic structure to come in better contact with the water column. All this is not only true for tropical, coral reef habitats: comparable results were obtained from North-Atlantic deep-water corals. Bacterial biofilms that cover the surface of these substrates are probably the basic food source for the meio-epifaunal community. Small fragments originating from degradation of biogenic structures effectively provide additional habitat complexity within the sediment, resulting in higher biodiversity by stimulating niche segregation.

Much less is known about the meiofauna associated with non-biogenic but anthropogenic substrates. The only biological study on a shipwreck dealing with meiofauna (Herdendorf *et al.,* 1995) was conducted in a deep-sea environment. Consequently, the study at hand will cover an untouched topic in marine biological research. This study will allow the comparison with biogenic substrates in terms of community structure and biodiversity and will enable us to assess the speed with which these stable communities are formed, but will also provide us with information on the specific morphological adaptations necessary for meiofaunal taxa to live on shipwreck surfaces. In this regard the epifaunal nematode families Epsilonematidae and Draconematidae can be expected to occur. As meiofauna constitutes a major food source for larger biota, these 2 aspects of the study are closely linked. Although decomposition of shipwrecks is active on a different time scale compared to biogenic structures, small fragments could be expected to litter the surrounding sediment, resulting in niche segregation.
Marine artificial reefs are described as "each material or each matter that is intentionally placed in a marine area, where that structure does not occur under natural circumstances and to mimic certain characteristics of a natural reef as a main goal (Jensen, 1998; Svane & Petersen, 2001; Seaman, 2000; Anonymous, 2003). Primary artificial reefs are constructed to influence physical, biological or socio-economic processes (Seaman, 2000). Structures, that mimic some characteristics of natural reefs, but with an other main goal, are defined as secondary artificial reefs (Bartholomew *et al*., 2000). Shipwrecks are examples of such secondary artificial reefs. Most studies about artificial reefs examine ecological aspects of fish populations (Svane & Petersen, 2001). The development of artificial reefs often results in an enrichment and diversification of the local fish community (Santos & Monteiro, 1997; Svane & Petersen, 2001; Charbonnel *et al*., 2002; Fabi *et al*., 2002; Løkkeborg *et al*., 2002). After all, those habitats function as a shelter against predators or strong currents as well as as a feeding area (Charbonnel *et al*., 2000). Artificial reefs thus form an extra habitat for fish, so that higher abundances are often present in comparison with the original natural surroundings (Jensen, 2002). Artificial reefs are also susceptible for the settlement of a wide range of benthic invertebrates and often develop successful communities (Sinis *et al*., 2000; Svane & Petersen, 2001).

Artificial reefs can influence the infauna of the natural nearby soft-sediments in different ways: (1) by changing the hydrodynamic regime and the physical characteristics of the sediments, (2) through the modification of the distribution and/or composition of the available food sources and (3) through the change of the biological interactions between different parts of the food web. One of those factors can dominate over the others or the different factors can act together (Ambrose & Anderson, 1990; Danovaro *et al*., 2002). The most dominant altered biological change could be the change in the predator-prey interaction (Davis *et al*., 1982; Posey & Ambrose, 1994). After all, reefs form a refugium for fish and invertebrate

predators, of which different species are dependent of the nearby soft sediments for food (Posey & Ambrose, 1994).
Artificial reefs also prevent soft-substrate ecosystems from being trawled by beam trawl fisheries. Fisheries represents the most widespread and biggest anthropogenic impact in marine environments (Dayton *et al.*, 1995). It has led to widespread disturbances of marine ecosystems. In the North Sea, there has been fishing activity for many centuries. Since the early 1960s, fishing intensity increased after the re-introduction of the beam trawl as the most common demersal gear employed in the flatfish fishery in the North Sea and by the improvements with regard to number of vessels, engine power, fishing speed and weight of trawling gears (Rijnsdorp *et al.*, 1998; Frid *et al.*, 2000; Piet *et al.*, 2000). Bottom-trawl fisheries can influence the infaunal communities of soft-sediments in different ways: (1) by scraping the seabed (2) by inducing sediment re-suspension and re-deposition and changing the grain size and sediment texture (Pranovi *et al.*, 2000; De Biasi, 2004) (3) by altering nutrient cycling (Mayer *et al.*, 1991) (4) through the reduction in habitat complexity (Collie *et al.*, 2000) (5) through the crushing of individuals or removal as by-catch (Kaiser & Spencer, 1995; Collie *et al.*, 1997). Trawling affects the structure, diversity, abundance, biomass and production of benthic communities (Collie et al., 2000; Frid *et al.*, 2000; Hermsen et al., 2003). Thus the absence of bottom trawling near artificial reefs may have a positive effect on the infauna of the natural nearby soft-sediments.

Hard substrate of the shipwrecks provides a model for other artificial hard substrate. Construction of offshore windmill farms is planned for the near future. Building these farms will entail the creation of large areas of artificial hard substrate, which will be colonised by a fauna different from the one living in the natural soft, sandy sediments of the area where the farms are planned. Results of this project will contribute to understanding and predicting the influence of these constructions on the biodiversity of the area.

Shipwrecks are suitable candidates for establishing marine protected areas. By the increased complexity of the environment they offer an area for the settlement of species typically associated with hard substrates which are rare in Belgian waters. In order to take decisions on these marine protected areas, it is important to estimate the diversity of these shipwrecks, and to assess their uniqueness, both in terms of species composition and ecosystem functioning.

Finally, there is an urgent need to develop adapted standard protocols to sample hard substrates. Very soon, construction will start on windmill farms. We want to be able to monitor the impact of these constructions using the most efficient, cost-effective techniques. Moreover, any standard protocols developed will be checked against international existing standards, making sure results from this project will be comparable to information collected elsewhere. Standards developed by ICES and other international organizations will be critically reviewed while developing protocols for this project, and checked for feasibility using the experience gained during earlier phases of the project.

Studies on North Sea shipwrecks with direct observations of benthic and particularly sessile fauna have been performed by Dutch scientists (Waardenburg 1988, van Moorsel *et al.,*1989, 1991). They prospected 22 shipwrecks along the Dutch coast. Biodiversity was estimated *in situ* and on video tapes. These methods revealed only a part of the biodiversity. Nevertheless, the results clearly indicate that shipwrecks are much richer than the surrounding sediments and appear as oases of life.
A preliminary campaign on board of the RV Belgica performed in July 2001 targeted a first wreck, the "Birkenfels" (ED50, N51° 39',040-E002°32',350, 156 m long, 42 m depth). The 4 samples collected show at least 37 macro-invertebrate species and 8 fish species. Not surprisingly, with at least 45 macro-species present (Massin *et al.,*2002), the "Birkenfels" shows a much higher biodiversity than nearly all the localities prospected with other techniques (see Cattrijsse & Degraer 2001; Cattrijsse, 2001) on the BCS. Moreover, several species, rarely mentioned for the Belgian fauna, have been found in large numbers (Massin *et al.,*2002).

Since then, the 2002 campaigns have added more than 80 new macro-species to the list (Zintzen *et al.,* 2003).
Part of this project was realised within the scope of the doctoral thesis of V. Zintzen, entitled "Biodiversity of shipwrecks from the southern bight of the North Sea"funded by an Action 2 program at RBINS. Initially three shipwrecks were under study (Birkenfels, Kilmore, Bourrasque). This project dealed only with sessile and vagile macrofauna (> 1mm long). In order to analyze a representative fraction of the diversity of hard substrates in the BCS, more shipwrecks needed to be investigated. Further, the study of meiofauna will fulfill an important gap on the functional diversity of these structures. The realization of these objectives could only be achieved trough an enlargement of the scientific teams and a substantial increase of the shipping and sampling time.

Objectives

The general objective of this research program is to assess the implications of added artificial hard substrates for regional biodiversity considerations. This objective can be further divided into the following questions:

Sampling protocols
- What could be standard protocols for the sampling of artificial hard susbtrate fauna in Belgian waters?

Macro- and meio-fauna of soft sediments around shipwrecks
- What is the community structure on the untrawled community around shipwrecks compared to well-studied soft sediments communities on the BCS?

Macro- and meio-epifauna on shipwrecks
- What is the macro- and meio-benthic diversity on shipwrecks?
- What are key species and dominating communities in the macro- and meio-benthic fauna?
- How is community pattern of the macro-epifauna on shipwrecks changing in space (along an onshore-offshore gradient) and time (at the scale of the year)?
- How is community pattern of the meio-epifauna on shipwrecks changing in space (horizontal *vesus* vertical surfaces) and time?

Physical environment
- What are the abiotic key drivers mostly responsible for the detected community patterns?

Aims of this project are to provide answers to all these questions, moreover, all collected material will be added in reference collections. The development of database and interactive web site on biodiversity of shipwrecks from the Belgian waters will be initiated. Scientific results have been disseminated through congress participation and papers publications (see annexe 1).
Finally for the general public, a brochure on shipwreck biodiversity has to be produced (see annexe8) and an illustrated book detailing the environment of shipwrecks and their most important species is in preparation.

2. Material and methods

The repartition and extent of natural and artificial hard substrates on the BCS

The available geo-referenced data of natural hard substrates were compiled in a map and their extent compared to the artificial hard substrates.
The amount of hard substrate available for colonization of epifauna was estimated from the obstruction data set of the Administration for Navigation and Coast of Belgium. This data set is a compilation of the possible obstruction to navigation or to fishery for the BCS.
For the 231 records which were almost exclusively shipwrecks, the length of 73 shipwrecks (average length: 80.9 m) and the width of 70 shipwrecks (average width: 11.4 m) were known from measurements done with multi-beam sonar. In order to calculate the total surface of these hard substrates, we used van Moorsel et al.,(1991) estimations. In their work on shipwrecks representative of the Dutch coast, they calculated that the ratio of shipwreck surface against its projected area lay between 4 and 7. The projected area was calculated by multiplying the length by the width. For shipwrecks where these values were unknown, we used mean values estimated from the pool of known dimensions.
Obstruction points were incorporated into a SIG (Mapinfo V6.5) and analyzed for their spatial allocation in relation to distance from the coast, navigation routes, harbours and mean distance between them.
The list of the different shipwrecks sampled during this research project are presented in the following table (Table 1) and figure (Figure 1)

Wreck	WGS-84 Coordinates	Date of sunk	Distance from the coast (nautical miles)	Length x Width x Height[a] (m)	Depth (MLLWS) (m)	Orientation	Sampling
Birkenfels	N 51°38',989 E 02°32',268	1966	29	156 x 18 x 22	37	174°	CTD, HE ; HM ; SE, W
Callisto	N 51°41',950 E 02°37',330	1959	29	146 x 19 x 8	28	28°	CTD ; HE
Garden city	N 51°29',170 E 02°18',320	1969	25	160 x 21 x 14	26	27°	CTD; HE; W
Kilmore	N 51°23',730 E 02°29',790	1906	17	87 x 13 x 8	30	46°	CTD,HE ; HM ; SE ; SM,W
John Mahn	N 51°28',930 E 02°41',350	1942	17	46 x 9 x 4	29	104°	CTD; HE,W
Duc de Normandie	N 51°25',524 E 02°36',345	1942	16	51 x 11 x 7	29	164°	CTD; HE, W
Sigurd Faulbaums	N 51°20',090 E 02°36'938	1940	12	93 x 21 x 6	22	63 °	SE
LCT 457	N 51°24',670 E 02°43',720	1944	12	63 x 10 x ?	21	67°	HE
Bourrasque	N 51°14',964 E 02°33',026	1940	8	74 x 12 x 3	18	81°	CTD, HE ; HM ; SE , W
LST 420	N 51°15',510 E 02°40',830	1944	6	109 x 13 x 4	8	128°	HE,W
Sperrbrecher 142 142 = Westebroek	N 51°16',650 E 02°49',780	1942	4	41 x 8 x 4	8	21°	CTD ; HE ; HM ; SE ; SM; W

Table 1. Coordinates and and basic information on the ten shipwrecks under study.
[a] The height as estimated from multibeam sonar images i.e. the highest structure above the seabed level.
? Unavailable data.
Sampling: CTD: abiotic parameters; HE: hard substrate epifauna; HM: hard substrate meiofauna; SE: soft substrate epifauna; SM: soft subtrate meiofauna, W:water for chlorophyll

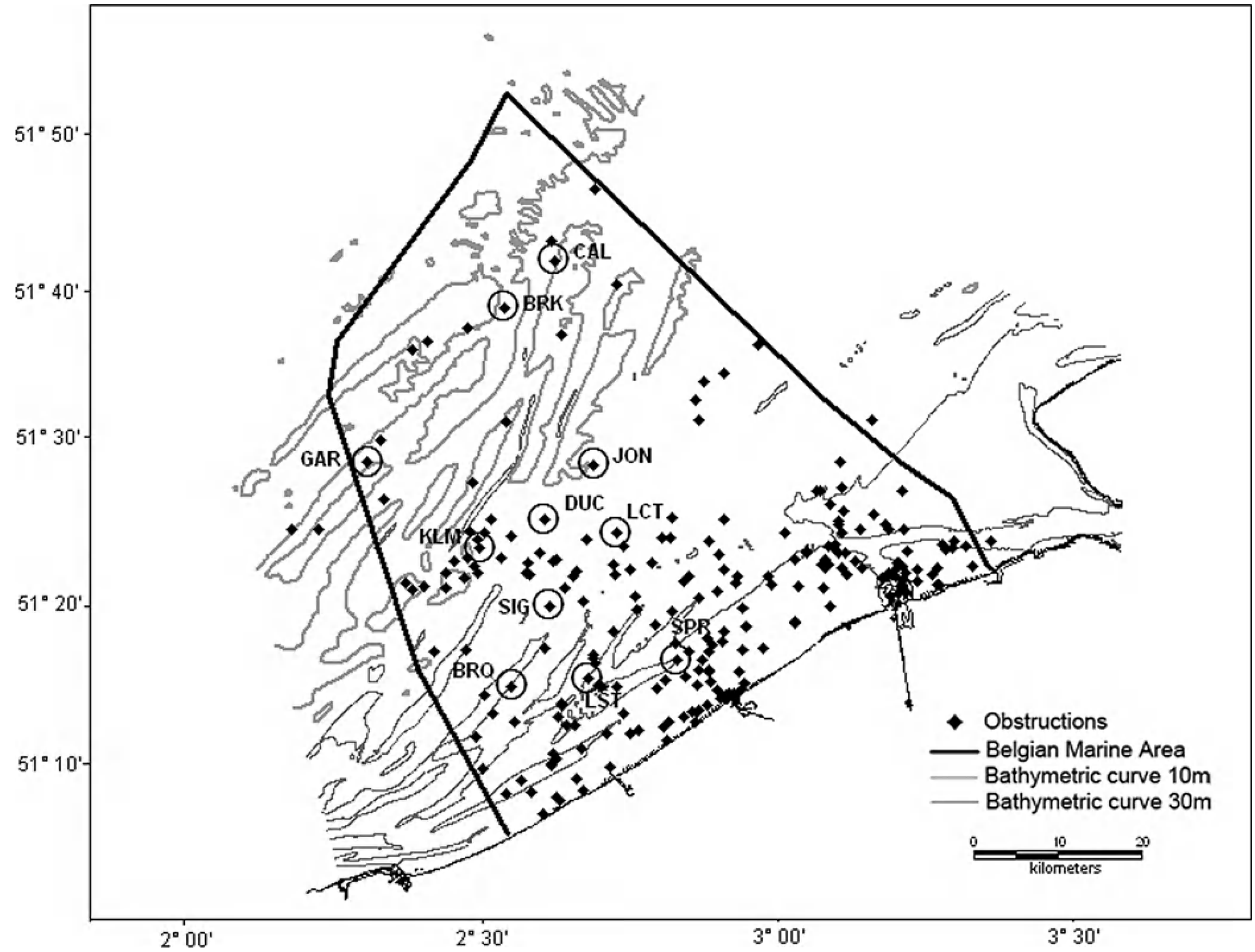


Figure 1. Localisation of investigated shipwrecks. BRQ: Bourrasque, BRK: Birkenfels, CAL: Callisto, DUC: Duc de Normandie, GAR: Garden City, JON: John Mahn, KLM: Kilmore, LCT: LCT 457, LST: LST 420, SIG: Sigurd Faulbaums, SPR: Sperrbrecher 142 142. Coordinates are WGS-84.
Source: Afdeling Waterwegen Kust (AWK), Belgium.

Meiofauna and Macrobenthos sampling

The new protocol setup by BEWREMABI partners concerning soft sediment sampling has been applied underwater for the first time and needed some technical adaptation. Enough air needs to be carried out by the divers in order to operate the air-lift device (Photo 1).

Photo 1 Soft sediment sampling using air-lift. Kilmore wreck 2005

Flow of air needs to be adjusted to achieve a proper suction in order to be able to sample the sediment. Design of the air-lift was made by A.Norro (Mumm) and one copy has been made at RUG. Adaptations have been carried out on the prototype device during BEWREMABI project; for example, a helicoidal valve was added to better adjust/control the air flow into the air-lift. This also permitted to use less air by sample than before. A quick connection device has also been fitted permitting an adequate and rapid fitting of the equipment underwater. That quick connection device needed to be stainless (underwater use) and able to provide enough air flow at the service pressure (intermediate pressure in Pa that is $9\ 10^{5}$ + depth x 10^{4}). Collecting bag needed several adaptations to ensure proper sampling without clogging.
For soft substrate macrobenthos collection, one standard frame was used; to ensure comparison and continuity with other experiments, the size of the frame remained the original 0.1026 m². From a practical point of view, this size corresponds to a frame having a considerable drag when operating underwater around North Sea Shipwrecks. To overcome this problem a foldable frame presenting less drag for the same sampling size was build (Photo 2).

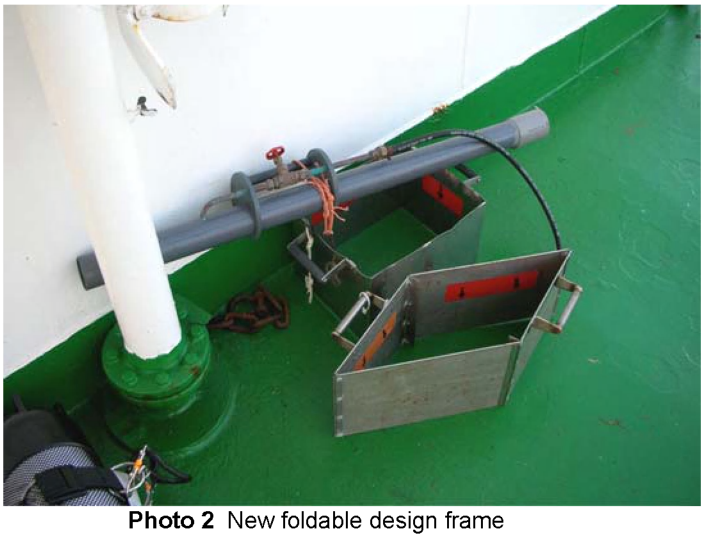


Photo 2 New foldable design frame

Invertebrates traps have been deployed during Belgica 2004/20 campaign and left overnight in order to capture small moving invertebrates; This first attempt not only showed the difficulty to recover the traps, from one dive to another, but it also appeared unsuccessful since after a full night of deployment, the baited trap was retrieved without capturing any animals; further trials will be required to improve this capture method.

Sampling strategies and techniques for soft substrate meio- and macrobenthos

Sampling strategy

Taking into account the limited number of samples that can be collected by divers versus the need for a large(r) number of samples needed to retrieve a representative sample of the benthic community structure, all samples will be focused solely on one type of habitat, the fine muddy sands of the macrobenthic *Abra alba – Mysella bidentata* community as described by Van Hoey *et al.,*(2004). This community has been selected because of (1) its high macrobenthic species richness and density, (2) the good scientific knowledge of its community structure in trawled areas of the BMA and (3) the consequent policy interest in this community within the framework of the future establishment of marine protected areas.
Based on existing side-scan sonar images of the soft substrates in the vicinity of shipwrecks, areas with a high probability of the community's presence (i.e. priority areas) will be selected. Each diving team will focus on one of the priority areas.
At each of the priority areas, one (or two) station(s) within the target habitat will be searched for and sampled for the meio- and macrobenthos. Before diving each diver will be briefed on how to distinguish between the different soft substrate habitats. Each diving team will collect both core and macrofauna airlift samples.
The number of stations to be sampled will depend on (1) the amount of air needed for the macrobenthos airlift sample and (2) the diving time window.
Combining the samples collected by all diving teams, a random sample of the habitat-specific meio- and macrobenthos of (a selection of) the shipwrecks will be retrieved.

Sampling techniques

Meiobenthos
At each station one core will be pushed into the sediment down to a depth of (approximately) 15 cm. After sealing the core at the top, the core will be gently pulled out of the sediment, sealed at the bottom and placed within the core rack.
Macrobenthos
At each station a frame will be pushed into the sediment down to a depth of approximately 10 cm. The sediment within the frame will be vacuumed with the macrobenthos airlift device, using a 1 mm mesh sized sample bag.
Environmental variables
At each station two cores (one for sediment analysis and one for chemical profile analysis) will be pushed into the sediment down to a depth of (approximately) 15 cm. After sealing the cores at the top, the core will be gently pulled out of the sediment, sealed at the bottom and placed within the core rack.
Because of the increased turbidity during the macrobenthos airlift sampling, it is advised to start with the core sampling (i.e. meiobenthos and environmental variable samples).

Study area and data origin

The study is executed on the BCS situated in the southern part of the North Sea. The BCS has a surface of 3600 km² and consists of a wide variety of soft sediment habitats. The area is mainly characterized by a very variable and complex topography through the presence of different sandbank formations (i.e. the Coastal Banks, the Flemish Banks, the Zeeland Banks and the Hinderbanks) that lie together in parallel groups (Trentesaux *et al.,* 1999). Consequently, the sediment types are highly variable over the whole area. Since the spatial distribution of the macrobenthos is strongly dependent of the physical surroundings, a high diversity of macrobenthic live is found on the BCS (Degraer *et al.,* 1999).

Within the framework of several projects 653 macrobenthos samples were collected at the BCS between 1994 and 2004 (MACROBEL). The samples were all collected with a Van Veen grab (sampling surface area: 0.1 m²) and sieved alive over a 1 mm mesh-sized sieve. All organisms retained were identified to species level and species-specific densities (ind/m²) were determined. The grain size distribution of a subsample was measured with a LS Coulter particle size analyzer: median grain size and mud content (volume percentage < 64 µm) were used as granulometric parameters.

Macrobenthos samples in the close vicinity of six shipwrecks at the BCS were collected in this study (Table 2). The criteria for selection were (1) shipwrecks large enough to be easily located, (2) in good condition to work with maximum security but sunk since at least 10 years and (3) located out of important navigation roads of the southern North Sea.

Shipwreck sites	Sampling years	Number of samples
Birkenfels	04-05	2
Kilmore	04-05	5
Bourrasque	04-05-06	15
LST420	05	2
Sperrbrecher 142	04	1
Sigurd Faulbaums	06	25

Table 2: Sampling effort for soft sediment macrobenthos

All samples from the Birkenfels, Kilmore, Bourrasque, LST420 and Sperrbrecher 142 were taken near the shipwrecks. The samples from the Sigurd Faulbaums were taken at 1 m (15 samples) and at 15 m (10 samples) from the shipwreck. All samples were collected by divers. At each station a frame (sampling surface area: 0.1 m²) was pushed into the sediment down to a depth of approximately 10 cm. The sediment within the frame was vacuumed with a macrobenthos airlift device, using a 1 mm mesh sized sample bag. All organisms retained were identified to species level and species-specific densities (ind/m²) were determined. At each station one core (Ø 3.6 cm) was pushed into the sediment down to a depth of approximately 15 cm. The grain size distribution of the core was measured with a LS Coulter particle size analyzer: median grain size and mud content (volume percentage < 64 µm) were recorded as granulometric variables.

Data analysis

Datasets

A general comparison between the macrobenthos of the BCS and of the shipwrecks was made based on a first dataset with 653 BCS-samples, 50 shipwreck-samples and 183 macrobenthic species. Rare species (all species that occurred in less than 2% of all samples with a density lower than 2 ind/sample) were excluded.

For a more detailed comparison, the differences between the macrobenthos near the shipwreck and in the surrounding environment were studied. A second dataset was made with the BCS-samples that lay in a radius of 5 km around the shipwreck, and the shipwreck-samples. A radius of 5 km was chosen because there were not enough samples (less than 3) at a narrower radius. Only the BCS-samples with the same community or transitional species assemblage as the nearby shipwreck-samples were selected. Only at the Bourrasque and the Sigurd Faulbaums enough samples (more than 3 since 3 = minimal replication) were taken to make the comparison, thus the samples of the other shipwrecks and their surroundings were removed from the dataset.

Unique species

If there were more than three (3=minimal replication) shipwreck-samples belonging to a community or transitional species assemblage found on the BCS, a comparison was made between the BCS-samples and the shipwreck-samples of the community or transitional species assemblage. Analysis of SIMilarities (ANOSIM) was used to test the statistic for significant differences ($p<0.05$) between BCS-samples and shipwreck-samples and to identify discriminating species (SIMilarity of PERcentages: SIMPER). Those analyses were done using the Primer software (Clark & Gorley, 2001). A univariate nonparametric test (Mann-Whitney U-test – STATISTICA software) was used to determine which species were found significantly more or less in shipwreck-samples compared to BCS-samples. Non-parametric test were used because the assumptions for parametric test, even after transformation, were not fulfilled.

SIMPER (SIMilarity of PERcentages) was used to identify discriminating species between the shipwreck-samples and the surroundings-samples. Univariate two-way analysis of variance (ANOVA-STATISTICA software) was used to determine which species had a significantly different abundance between the shipwreck-samples and the surroundings-samples, taking into account the different communities or transitional species assemblages. If necessary, a log (x+1) transformation was performed to meet the required assumptions.

Physical habitat

Differences in median grain size and mud content were investigated between the shipwrecks and their surroundings. Univariate two-way analysis of variance (ANOVA-STATISTICA software) was used to test for differences in granulometric variables between shipwreck-samples and surroundings-samples, taking into account the different communities or transitional species assemblages.

Community structure

The community structure was investigated by two multivariate techniques: group-averaging cluster analysis based on the Bray-Curtis similarity and Correspondence Analyses (CA), based on the first dataset. The abundance data were fourth root transformed prior to the cluster analysis and CA. The results of these techniques were compared to distinguish between all four communities and three transitional species assemblages as described by Van Hoey *et al.,*(2004). All community analyses were done using the Pcord4 software.

Species abundance data of shipwreck-samples and surroundings-samples were subjected to Correspondence Analyses (CA). The abundance data were fourth root transformed prior to the CA. Analysis of SIMilarities (ANOSIM) was used to test the statistic for significant differences ($p<0.05$) between the shipwreck-samples and the surroundings-samples. ANOSIM was done using the primer software and a CA was done with the Pcord4 software.

A comparison between the shipwrecks and their surroundings was made on the basis of three univariate parameters. The following univariate indices were used to make the comparison: (1) total density N, (2) species richness, S, expressed as number of species per sample (i.e. per 0.1 m^2) and (3) the exponential form of the Shannon-Wiener index N_1. All indices were calculated with the Primer software. Univariate two-way analysis of variance (ANOVA-STATISTICA software) was used to test for differences in density, species richness and diversity between shipwreck-samples and surroundings-samples, taking into account the different shipwrecks. If necessary, a log (x+1) transformation was performed to meet the required assumptions.

Influence of distance.

The effect of distance from a shipwreck was investigated using the samples of the Sigurd Faulbaums. On the basis of the granulometric parameters and three univariate indices, a comparison was made between the 1 m-samples and the 15 m-samples. The following univariate indices were used to make the comparison: (1) total density N, (2) species richness, S, expressed as number of species per sample (i.e. per 0.1 m^2) and (3) the exponential form of the Shannon – Wiener index N_1. All indices were calculated with the Primer software. Univariate one-way analysis of variance (ANOVA – STATISTICA software) was used to test for differences between 1 m-samples and 15 m-samples. If necessary, a log (x+1) transformation was performed to meet the required assumptions.

Species abundance data of 1 m-samples and 15 m-samples were subjected to Correspondence Analyses (CA). The abundance data were fourth root transformed prior to the CA. Analysis of SIMilarities (ANOSIM) was used to test the statistic for significant differences ($p<0.05$) between 1 m-samples and 15 m-samples and to identify the discriminating species (SIMilarity of PERcentages: SIMPER). ANOSIM and SIMPER were done using the Primer software and a CA was done with the Pcord4 software. A univariate nonparametric test (Mann-Whitney U-test – STATISTICA software) was used to determine which species had a significantly different abundance between the 1m-samples and 15m-samples. Non-parametric test were used because the assumptions for parametric test, even after transformation, were not fulfilled.

Sampling strategies and techniques for hard substrate meiobenthos

Sampling strategy

Since no information of the meioepifauna of hard substrates at the BCS is available at present, a stratified random sampling design has been selected in order to gain (1) an ample view on the meioepifaunal community structure and (2) a representative view on the community structure of different habitats.

The different strata (i.e. habitats) to be taken into account are e.g. the macroepifaunal habitat, the soft sediment deposits on the wreck surfaces and the horizontal versus vertical surfaces of the shipwrecks (i.e. stratified sampling design). At each of these strata (at least) two stations from separated stratum patches should be sampled (i.e. randomized sampling design).

It is advised to use the same sampling strategy for the macroepifauna and, thus, to collect both meio- and macroepifaunal samples at the same stations. This will allow to (1) directly compare meio- and macrofauna community structure from different habitats and (2) shorten the diving time needed.

At each station one meioepifauna sample will be collected, using quadrants. Because of the inevitable loss of meiofaunal organisms the data retrieved should be regarded as semi-quantitative.

Sampling techniques

Meiobenthos

The meiofauna from macroepifaunal habitats will be collected from the scraping epifauna quadrant samples (in cooperation with V. Zintzen): *on board*, the meiobenthos will be extracted from scraping epifauna quadrant samples.

Environmental variables

In case the meiobenthos from sediment deposits is sampled, a sample for sediment analysis will be collected by scooping up the sediment with a 50 ml recipient.

Study sites

Two shipwrecks of the BCS have been studied in this study. The Kilmore (N 51°23',730 E 02°29',790) is located at 17 nautical miles from the shore line (32 m depth). The Sperrbrecher 142 (N 51°16,65 E 02°49,78) is located at 4 nautical miles from the coast line (12 m depth) and is as such a more onshore wreck more protected by sandbanks (see table 1 and figure 1).

A stratified random sampling design has been selected. A detailed description of the sampling techniques is presented in the 'Standard protocol for sampling techniques of epifauna on hard substrates' as one of the outcomes of the BEWREMABII project. We also refer to Zintzen *et al.,*(2006) for a detailed description.

The meiofauna has been collected from the scraping epifauna 25 x 25 cm quadrant samples (in cooperation with V. Zintzen). Scraped organisms have been collected in plastic bags. On board, samples were preserved in buffered 4% formalin. The meiobenthos was further extracted from scraping epifauna quadrant samples, by sieving over 1 mm sieves. The lower mesh size for meiofauna was 38 µm. Due to the inevitable loss of meiofaunal organisms during sampling, the retrieved data should be regarded as semi-quantitative. The same sampling strategy for the meio-and macroepifauna is used, in order to be able to (1) directly compare meio- and macrofauna community structure from different habitats and (2) shorten the diving time needed. Following samples have been analysed for this study (Table3):

	Surface orientation	2 april 2004	7 July 2004
Kilmore	Horizontal	KLM AH 1 (1)	KLM JH 1 (2)
		KLM AH 2 (5)	KLM JH 2 (7)
	Vertical	KLM AV 1 (2)	KLM JV 1 (1)
		KLM AV 2 (4)	KLM JV 2 (4)
		KLM AV 3 (7)	
Sperrbrecher 142	Horizontal		SPR JH 1 (2)
			SPR JH 2 (5)
	Vertical		SPR JV 1 (3)
			SPR JV 2 (6)

Table3 :Sample analyzed for meiofauna on shipwreck; number in between brackets refer to the sample numbers of the BEWREMABI project, KLM= Kilmore; SPR= Sperrbrecher 142

Meiobenthos taxa and nematode genera were enumerated and identified according to the methods described in Steyaert *et al.,*(1999).
Food type preferences of nematodes were evaluated, using the feeding type classification of Wieser (1953).

To test statistic differences between shipwrecks, orientations and seasons, univariate and multivariate two-way ANOVA was applied on non-transformed abundances (Statistica 6.0). A TWINSPAN analyses was executed including all nematode genus abundancies. Rare species were excluded from the analyses, using the PcOrd 4 software options; cutlevels were 0, 0.5, 1.5, 4.5, 18.

Epifauna sampling

Identity of shipwreck communities

In a first attempt to contrast the artificial hard substrate fauna from the soft-sediment fauna, four shipwrecks (Birkenfels, Kilmore, Bourrasque and Sperrbrecher 142, see table 1) located along a cross-shore transect were sampled from 2001 until 2004.
All the living fauna within frames of 25 x 25 cm selected at random were scrapped on the surface of shipwrecks by SCUBA divers. On board, animals were relaxed in a 3.5 % $MgCl_2$ solution for two hours and then transferred to a buffered formalin solution (final concentration 4 %, pH 8.2-8.4). Later on, specimens were transferred to 70 % buffered alcohol for permanent storage. Before transfer to formalin, some of the samples were sieved over a 1 mm mesh size sieve and then over a 28 µm mesh size sieve to isolate the macro-epifauna from the meio-epifauna.
The macro-epifauna samples were then sorted under a binocular and species (>1 mm) were identified to the lowest possible taxonomic level and counted. Colonial species were considered as present or absent. The raw data set is composed of 80 samples for 181 taxa (further referred to as species) and was used for comparison with the macrofauna of the soft sediment (MACROBEL database, Degraer et al., 2006).

During the spring and summer periods, samples (N=35) from the four shipwrecks were scrapped for biomass analysis. The epifauna inside a 0.0625 m^2 frame was removed and transferred to plastic bags. *On board*, the samples were directly frozen (-80°C).
Dry weight was measured after constant weight was attained in an oven at 80°C. Since the samples were often large, ash fee dry weights were measured on a subsample. Ashes were obtained after burning the subsample in a furnace at 500°C for 12h. Ash free dry weight was the difference between dry weight and the weight after the burning process.
The biomass of soft sediment from the coastal area (<5 nautical miles from the coast) were estimated from Van Veen grabs (S=O.1026 m^2, N=50). The animals were sieved alive over a 1 mm mesh-sized sieve. Ash-free dry weight per higher taxon and per sample was determined by drying the individuals for 72 hours at 60 °C to a constant dry weight and then combusting them for 2 hours at 500 °C. The AFDW was determined by subtracting the ash weight from the dry weight.

Spatial variability

In a second step, nine sites (Birkenfels, Callisto, Garden City, Kilmore, John Mahn, Duc de Normandie, LCT457, Bourrasque and LT420, see table 1) were sampled during a two months period (May and June 2005) to study the spatial variation in community structure. The preliminary studies showed that both photographic documentation and collection of organisms were needed to provide useful information on the epifauna communities of subtidal artificial hard substrates.
Sampling was achieved during day time. Photographic techniques were used to assess general features of the different communities at the scale of the individual shipwreck. A 30 m tape was deployed by divers on the upper structures of each shipwreck and digital pictures of 0.5 x 0.5 m quadrats were taken every 5 m with a digital camera recorder (Sony PC 330, 3.2 Mpix) in a Mako housing and lighting (Light & Motion). After completion of the first set of pictures, the tape was deployed in the opposite direction of the first transect and the process started again.
Due to the very poor visibility conditions, it was often impossible for the divers to locate themselves precisely on the shipwrecks. The changing and often poor visibility conditions on sites prevented for detailed analysis of pictures.
The manual collection of a selected faunal assemblage corrected for this and allowed for species identification and enumeration. These samples were randomly taken on an a priori defined faunal assemblage dominated by the hydrozoan *Tubularia indivisa* and/or *Tubularia larynx*. These assemblages are known to harbour a diverse faunal association on these sites (Zintzen et al., 2006).
All organisms within quadrats of 0.25 x 0.25 m were scrapped off of vertical surfaces in triplicate. All organisms were carefully collected in a plastic bag. The loss of vagile material by currents was kept low because most of the species were in close contact to the tubulariids and tended to protect themselves by staying close to their substrate.
The samples were sorted under a binocular microscope and macro-species (>1 mm) were identified to the lowest possible taxonomic level and counted. Colonial species were noted as present or absent.
Ash free dry weights (AFDW) were calculated for each species in each sample. First, wet weight (in alcohol) per species was determined to the nearest mg. Prior to weighting, specimens were blotted on absorbent paper to remove excess alcohol. Specimens weighting less than 1 mg were given the assigned value of 1 mg. For the taxa represented by low biomass values, ash free dry weights were calculated by using conversion factors found in the literature (Rumohr et al., 1987; Ricciardi & Bourget, 1998; Galéron et al., 2000).
For the more important taxa in terms of biomass, we calculated our own wet weights to ash free dry weights conversion factors. Therefore, taxa were weighted wet, dried (48h at 70°C), re-weighted (dry weight) and then burned at 500°C for 12h. Ash free dry weight is the difference between dry weight and the weight after the burning process. Specimens were

kept in preservatives which have a known effect on their biomass (Brey, 1986; Rumohr et al., 1987; Gaston et al., 1996; Pakhomov, 2003; Wetzel et al., 2005).
The sorting and taxonomic work did not allow freezing of the samples for conservation. In this case, Gaston et al.,(1996)recommended fixing organisms in a formalin solution prior to transfer them into alcohol for sample processing. However, there is no agreement on which factor to apply to correct weight loss. Consequently, we multiplied our values by a factor of 1.2 as estimated by Rumohr et al.,(1987) and used by Cusson & Bourget (2005). This factor has to be considered as a minimum one.

Temporal variability

Initially, the Kilmore shipwreck had to be sampled on a seasonal basis from December 2003 to December 2005. However, adverse weather conditions prevented sampling on many occasions and the Kilmore was sampled on height dates: December 2003, April 2004, July 2004, October 2004, March 2005, June 2005, August 2005 and October 2005.
On each date, all the living fauna within frames of 25 x 25 cm selected at random on the *Tubularia indivisa* community were scrapped on the surface of shipwrecks using SCUBA. This was achieved in triplicate on surface vertically oriented. The samples were then processed as explained above. Systematically attached taxa or taxa invariably found living in association with *T. indivisa* were noted. Taxa are further considered as species in the text.
On every sample, wet weight (in alcohol) of the nine most important species in term of biomass was weighted individually to the nearest mg. These nine most important taxa were determined from a complete weighting of the samples from June 2005. We calculated wet weights to ash free dry weights conversion factors in triplicate for each species and used a correction factor of 1.2 for storage in preservative.

Epifauna analysis, biological data, univariate and multivariate statistics

Univariate summary variables used were the species richness (S), the Simpson index (D) (Magurran, 2004), the average taxonomic distinctness (Δ^+) and the variation in taxonomic distinctness (Λ^+) (Clarke & Warwick, 1998a; Clarke & Warwick, 2001a). True species richness was estimated with the Chao2 nonparametric estimator (Chao & Lee, 1992). Difference for dominance pattern across habitats was tested by comparing the slope of the rank/abundance plot (Whittaker, 1965) using Kolmogorov-Smirnov two-sample test (Sokal & Rohlf, 1995).

Generally, multivariate analyses were based on Bray-Curtis similarity between samples or taxonomic distance (Clarke & Warwick, 1998b). These matrix were then used to explore the pattern of community structure among samples by means of ordination with non-metric multidimensional scaling (nMDS) and clustering by group-averaging (Clarke, 1999). Prior to analysis, abundances were square root or double square root transformed to give more weight to the less abundant species. The groups a posteriori defined by the cluster and ordination analysis were tested by a one-way ANOSIM which is a multivariate test based on the corresponding rank similarities between samples in the underlying triangular similarity matrix (Clarke & Warwick, 2001b). Non parametric multivariate analysis of variance was used to test for difference between sites using PERMANOVA (Anderson, 2001).
The groups of sites resulting from the multivariate analysis were characterized by their indicator species. We used the indicator value (IndVal) coefficient developed by Dufrêne & Legendre (1997). A species is indicator of a group if it occurs on most of the samples from this group (specificity) and if it is poorly represented on the other groups (fidelity). The statistical significance of the species indicator values was evaluated using a randomization procedure (999 randomizations). A species is considered indicator of a group if the results of two tests are significant at a level of 0.05: a t-test computing the weighted distance between randomized values and the observed value, and the rank of the observed value among the decreasing ordered randomized value distribution.

Sampling techniques for abiotic parameters

38 CTD profiles have been taken during the project. The profile was taken just after the diving operation stopped. Some profiles were missing when the sampling was operated from rented boat and when CTD probe was not available. CTD were taken to characterise the specific sampling condition in the abiotic spectral window available from the analysis of database information (see below). We added Secchi disk measurement to our routine abiotic protocol (see annexe 2 for a list of different studied sites where CTD and Secchi data were taken).
Direct current measurement took place during Belgica cruise 2004/20, 2005/14 and 2005/21 using the hull mounted Acoustic Doppler Current Profiler (ADCP). The measurements were used to evaluate the current on site when sampling as well as to optimise diving windows.
A Niskin bottle (1,7l) was used to take water close to the shipwreck where biological sampling takes place. Water was filtered on pre-tarred GFC filter for suspended matter measurements. Due to technical problems, only data from sample taken on 27/5/2004 are available today. However, suspended particulate matters data derived from satellite images have been obtained from Mumm.
The collection of abiotic parameters was completed by using database information. Query of available database has been undertaken for temperature, salinity and turbidity fields at the position of the shipwrecks and on the surrounding 5 nautical miles (NM) around them. Belgian Marine Data Centre (BMDC) provided surface value for the period 1987-2005 as well as underway data taken from R/V Belgica for the period 1984-2006. VLIZ provided some more data from IMERS database as well as underway data taken from R/V Zeeleeuw.
Water current was investigated using modelling tools. Some measurement made by the hull mounted ADCP on board r/v Belgica are also available.
During Belgica cruise multibeam maps of the Kilmore and the Birkenfels have been acquired with the help of the Fund for Sand Extraction from the FPS Economy.

Data mining on available databases

Temperature, salinity and suspended particulate matter data have been searched on the following available databases (Table4):

odas	midas	bmdc	wreck
130901			cal
514990			ddn
35525			gdc
1200500		107	lst
629716			jhm
1065592	1313655	113	spe
442733	106934	86	klm
775876	289922	92	bou
128404	43698	29	bir
876054	277312	202	lct
3288659	2031521	629	total

Table 4 Number of available records from odas, midas and bmdc databases. Wreck names: cal for Callisto, ddn for Duc De Normandie, gdc for Garden City, lst for LST420, jhm for John Mahn, spe for Sperrbrecher 142, klm for Kilmore, bou for Bourrasque bir for Birkenfels and lct for LCT457.

To work on a meaningfull set of data, the search was extended to a zone of 5 NM around BEWREMABI shipwrecks sites.
BMDC (Belgian marine data center) provided data starting in 1987. They are presented graphically hereafter (in the results part of this report) for all sites.
Elementary statistics such as mean, standard deviation, median, minimum and maximum were computed on these data. Number of data point is also indicated.

IMERS data have been added when available. All together, that source of data provided 629 records.
Most of the temperature-salinity measurements were taken by CTD. Plessey-SCTD has been used till 1989 when Seabird SBE9 and SBE19 took over on R/V Belgica. However, Beckman RS 7B precision salinometer and Guildline portasol 8410 salinometer were also used for salinity evaluation of some samples. Temperature and salinity values used here are sub-surface values (3m). Nevertheless, due to the well-mixed water column, these sub-surface values remain representative for the whole water column.
Odas (underway data from R/V Belgica) provided 5800291 records for all site together while Midas, underway Zeeleeuw provided 2031521 records for the five shipwrecks under consideration. (see table4). Sea-Bird temperature and salinity underway data system (SBE21) from R/V Belgica include two thermometers one in the lab used for the salinity computation from the conductivity measured by SBE 21 system and one SBE38 close to the water inlet located in the bulb (bow) of the vessel.
Sub-surface water temperature time series provided by the Flemish hydrography (MFB-AWK) started 1 June 2001 with a time step of 10 min. That series, ended for this study, on the 10 May 2006 given 248022 records of subsurface water temperature for the station Westhinder . We note that Westhinder station is very close (~2 NM) to Kilmore wreck.
Data return form *WODB* (World Ocean Database) was very low (only few by sites) and most of the time (always after 1987) already available from BMDC.
Midas (underway data From R/V Zeeleuw) were finally not yet included and used here.
Underway data have been used to compute monthly mean values for temperature and salinity over the multiple years of available measurements. Minimum and maximum values are also presented. They are min and max value taken from the individual data. Inter-annual variability for a given wreck is indicated as standard deviation from the monthly mean values and is presented in the table proposed for every BEWREMABI sites.
As a general matter, temperatures are available from 1993 while salinities are generally available after 1997.
Results are proposed in the form of table containing temperature and salinity, monthly minimum, monthly maximum, monthly mean values, monthly mean standard deviation.

CTD and related available data

The 38 CTD profiles acquired within BEWREMABI were taken using SBE 19 or SBE19plus instruments. Four different instruments have been used all from the manufacturer SeaBird. S/N 3078 Model SBE19 and S/N 4126, 4427, 4930 model SBE 19plus. The first step of the post-treatment is the transformation of the binary raw data information into engineering units. Here we transformed every file using the calibration information provided by the manufacturer and that for the four different instruments. Measured pressure was transformed in meter of sea water (msw). Temperature and conductivity were kept at this stage in order to adjust the timing of the measurement for salinity computations. Photosynthetic Active Radiation (PAR) and Optical BackScatterance (OBS) were also computed when available.
Even if thermal stratification is very weak in the Southern North Sea, alignment of temperature and pressure signals have been achieved as requested by the manufacturer. Some filtration has been applied as well as a split between up and down casts. Name of the profile gives the date of sampling. For instance, the graph featuring 040402 show a profile taken on 2 April 2004

Suspended particulate matter

Suspended particulate matter has been obtained from satellite data (REMSEM team at MUMM) for all sites.
The Sea-viewing Wide Field-of-view Sensor (SeaWiFS)[i] aboard the SeaStar spacecraft and MODerate resolution Imaging Spectro-radiometer (MODIS)[ii] aboard the satellite EOS AQUA measure the sun reflectance at the Top Of Atmosphere (TOA) respectively at 8 bands and 9

bands in the visible and near infrared wavelengths. The SeaDAS[iii] software is used to process these TOA into atmospherically corrected reflectance by removing atmosphere contributions (air, ozone and aerosols scattering and absorption) and sea-water interface effect from the TOA reflectance, providing the water-leaving reflectance. Finally, a bio-optical model calibrated for the Belgian coastal waters, following the method described in Nechad *et al.*,(2003), is applied to SeaWiFS and MODIS water-leaving reflectance, ρ_w^{667nm} and ρ_w^{670nm} respectively at bands centered around 670nm and 667nm to be converted into total suspended matter concentration (TSM). The formula used to compute TSM from SeaWiFS and MODIS data are the following:

$$TSM_S = 4.29 + \frac{56.68\ \rho_w^{670nm}}{0.187 - \rho_w^{670nm}}\ [mg/l], \quad TSM_M = 4.34 + \frac{56.10\ \rho_w^{667nm}}{0.187 - \rho_w^{667nm}}\ [mg/l]$$

In addition to these data, Secchi disk measurements have been taken when available resulting in 27 measures available and used in a similar way as the CTD casts (see above)

Water Current data

Water current data presented here (see result part of this report) were taken using the r/v Belgica hull mounted WH 1200 Hz RD Instrument ADCP current profiler. Sampling rate is 5 sec 1 min. filtered. The data are vector averaged every 10 min.

Water Current model results

Model results were obtained using the new 3D operational model developed at MUMM (Pison & Ozer 2003). The model based on the COHERENS code (Luyten *et al.,* 1999) is run on an approximately 750 m square grid and on a daily basis inputting as forcing meteorological forecast available from UK met Office. Boundary conditions are provided by larger scale model using the nesting methods. The outputs of the model include profile of the current at the given location as well as depth averaged values. As a general matter currents rose are build on depth averaged current that are computed every 10 minutes.
The runs started in august 2004 and were stocked for nearly a full year resulting in at least 230 days of data for every wreck sites. Missing data resulted mainly from missing meteorological forecast and from technical problems.

Logistics

Logistic responsibles for all field activities during this project are mentioned in the annexe 3 ; RBINS has been a major key element to organize the practical aspect of this research.

Technical diving activities.

A minimal diving qualification was required for all divers in order to allow safe underwater operation and collect of samples; the following criteria were met: 3 stars diver (CMAS or equivalent), able to recognize major phyla and if possible to help taking pictures and video.
Nitrox breathing mixture (EAN) started during year 2004. By providing the diver with mixture containing more oxygen, the bottom time requiring no-decompression was increased by 5 to 10 minutes depending on the depth. This is an important improvement since more samples can be taken conserving the same level of safety for the diver.
From 2005 generalization of the use of Nitrox occurred and blending was operated *on board* research vessel when required. Of course, this technique required extra-care and specific equipment compared with air-diving but expertise and equipment were available inside BEWREMABI consortium.

Moreover, Closed Circuit Rebreather (CCR) started to be use during the 2006 field work. This technique proved to be operable safely and efficiently from our research vessel. Using such equipment it is possible to further increase the no-decompression bottom time keeping unchanged decompression safety factors.
From an operational point of view, it was difficult to convince some divers to start using Nitrox breathing mixture. Reasons have to be found on the extra formation needed as well as on diving gear transformations. This resulted in diving group composed by divers not using same breathing mixture. However, if that has no impact on safety of the diver, scientific work could not be optimized in such case.

Divers

The following divers belonging to one of the participating scientific institutes were involve in BEWREMABI activities : Delforge, C., Hernandez T., Mallefet J., Norro, A., Vanden Berghe, W., Schils, T., Zintzen V.
Volunteer divers, recruited through Mumm and the Lifras scientific commission, were able to join and to provide significant help during field work: Backx, M., Demoulin PB., Knuts R., Laitat Y., Simon A., Van Espen, M.
VLIZ used his contacts to gather sport divers that were keen on devoting their free time to aid the scientists of BEWREMABI in collecting the samples. In addition to his two staff member, VLIZ recruited 5 volunteers that could meet all certifications to qualify as a diver volunteer: Cray, F., Gyssens R., Marsham, D., Rooms G., Van Hoydonck, G., Verkemping Y.
VLIZ took insurance for liability during the diving operations.
In order to operate secure and safe VLIZ adopted and approved a diving procedure similar to the safety procedure applied on board the R.V. Belgica.

Vliz support to BEWREMABI

Diving material
To support the diving operations VLIZ purchased an air compressor to fill the airtanks of the divers when two dives were planned on the same day or when diving was taking place on consecutive days. The air compressor was taken *on board* the Zeeleeuw and remained available for BEWREMABI throughout the project. Other material that was purchased by VLIZ included personal safety material that was available to divers (knives, power whistles, decoy buoys and strobe lights). As an incentive and reward for their efforts divers could claim new small personal diving equipment if those items were lost or damaged during dives.
Shiptime
VLIZ has provided ample shiptime of both the Zeeleeuw and the RIB Zeekat to support the diving operations on shipwrecks. Table 5 shows the number of days and hours at sea with R.V. Zeeleeuw at sea for each year.

	Days at sea	Hours at sea
2004	3	21
2005	14	125
2006	9	75

Table 5: R.V. Zeeleuw shiptime use for BEWREMABI project

Between 10th August 2004 and 23th June 2006 49 trips were scheduled but resulted in only 25 trips with dives on the Zeeleeuw (see annexe 3 for a complete list). On a small number of such the dive team went to the site but the dive was cancelled at the very last moment for safety reasons. Table A3-2 (see annexe) shows the number of days scheduled in the cruise programme of the Zeeleeuw and what wreck(s) was visited during the trips that were not cancelled to adverse weather conditions. All cancelled trips were solely due to weather conditions, ie. wave heights above security height of 1m.

BEWREMABI field work: a general overview

Table 6 presents one overview of all the field work achieved during the project. This table illustrates the sampling effort during this project: 4 different ships were used (Blue Thistle, Stream, R.V. Zeeleeuw and R.V. Belgica); 45 cruises have been organised and 24 have been executed. All cancelled for bad weather condition but one for Vessels breakdown. 288 Man-dive (Man –dive is a measure of the man power needed to achieve the sampling) have been executed without any accident.
Belgica cruise 2004/20, 2005/14, 2005/21 and 2006/14 have been organised for BEWREMABI.(Cruise reports are available from www.mumm.ac.be/). 2006/14 Belgica cruise was cancelled due to Vessel breakdown. It was unfortunately not possible to obtain a replacement cruise on Belgica or Zeeleeuw. Due to the very poor visibility around the Sperrbrecher 142, BEWREMABI sampling did not concentrate on this site.
If at the beginning BEWREMABI was concerned by only five sites Birkenfels, Kilmore, Bourrasque, LCT457 and Westerbroek, it became clear that some sites extension was needed both in order to best characterise the wreck biodiversity and/or in order to find the required substrate to sample. Finally, the project ends up with Callisto, Duc de Normandie, LST 420 Garden-city and John Mahn in addition to the five initial shipwrecks.

Scientific diving BEWREMABI Project

date	nb dive	M dive	nb s H	nb s V	nb soft	nb core	fish tr	niskin	ctd	secchi	adcp	multbeam	video	photo	vessel	Wrk 1	Wrk 2
19/02/2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BT		
14/03/2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BT		
30/03/2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BT		
2/04/2004	2	16	3	3	1	12	0	0	2	0	0	0	0	0	BT	KLM	KLM
27/05/2004	2	14	5	6	0	0	0	0	0	2	0	0	0	0	ST	CAL	BOU
26/07/2004	2	18	8	9	0	0	0	2	2	2	0	0	30m	0	BT	KLM	SPE
10/08/2004	1	7	1	4	0	0	0	1	1	1	0	0	30m	1	ZL	BOU	
11/08/2004	1	9	?	?	1	3	0	1	1	1	0	0	30m	0	ZL	SPE	
15/09/2004	1	6	0	0	0	0	0	0	1	0	1	1	1	0	BE	KLM	
16/09/2004	1	8	4	3	0	0	2	1	1	0	2	2	0	1	BE	BIR	
17/09/2004	1	2	0	0	0	0	0	0	0	0	1	0	0	0	BE	BIR	
8/10/2004	2	14	8	6	5	12	0	1	2	0	0	0	0	0	DS	KLM	BOU
2/12/2004	1	9	0	0	0	0	0	1	1	1	0	0	0	0	ZL	SPE	
18/01/2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
4/03/2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
18/03/2005	1	6	0	4	0	0	0	1	1	1	0	0	0	1	ZL	KLM	
18/04/2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
2/05/2005	1	8	0	5	0	0	0	1	1	1	0	0	30m	1	ZL	BIR	
3/05/2005	1	10	0	5	3	6	0	1	2	1	0	0	0	0	ZL	KLM	SPE
4/05/2005	2	9	0	7	2	6	0	2	2	1	0	0	30m	1	ZL	SPE	BOU
18/05/2005	1	8	0	3	1	1	0	1	1	1	0	0	30m	0	ZL	BIR	
2/06/2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
3/06/2005	2	20	0	17	3	6	0	2	2	2	0	0	ddn 20m	0	ZL	DDN	LST
15/06/2005	1	6	0	3	0	0	0	1	malfun	1	1	0	30m	0	BE	KLM	
17/06/2005	1	6	0	6	0	0	0	0	1	1	1	0	30m	0	BE	CAL	
27/06/2005	1	8	0	6	0	0	0	1	1	1	0	0	2*30m	1	ZL	GDC	
28/06/2005	1	4	0	3	0	0	0	1	0	1	0	0	30m	0	ZL	JHM	
29/06/2005	2	9	0	9	0	0	0	2	2	1	0	0	30m	1	ZL	LCT	JHM
17/08/2005	2	18	3	8	0	0	0	2	2	1	0	0	klm1:2*30m	0	ZL	KLM	KLM
30/08/2005	0	0	0	0	0	0	0	0	1	1	0	0	0	0	ZL		
12/09/2005	1	6	0	2	0	0	0	1	1	1	1	0	30m+1	0	BE	KLM	
15/09/2005	1	6	0	6	0	0	0	1	0	0	1	0	0	0	BE	BIR	
13/10/2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
14/10/2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
27/10/2005	1	5	0	3	0	0	0	1	2	2	0	0	2*30m	0	ZL	KLM	
10/11/2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
24/11/2005	1	3	0	0	3	12	0	0	1	1	0	0	0	0	ZL	BOU	
25/11/2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
8/03/2006	1	6	0	0	4	12	0	0	1		0	0	0	0	ZL	BOU	
9/03/2006	1	3	0	0	0	0	0	0	0		0	0	0	0	ZL	BOU	
24/03/2006	0	0	0	0	0	0	0	0	1	1	0	0	0	0	ZL		
6/04/2006	1	6	0	0	0	0	0	0	1	1	0	0	0	0	ZL	KLM	
11/05/2006	2	12	0	0	4	6	0	0	2	2	0	0	0	3	ZL	KLM	BOU
8/06/2006	2	8	0	0	0	0	0	0	2	2	0	0	0	4	ZL	CAL	KLM
21/06/2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
22/06/2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ZL		
23/06/2006	2	8	0	0	0	0	0	0	malfun	0	0	0	0	4	ZL	LCT	KLM
3-7/7/2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BE		
6/09/2006	2	10	0	0	0	0	0	0	0	0	0	0	0	4	BT	BIR	KLM
Gr Total	**45**	**288**	**32**	**118**	**27**	**76**	**2**	**25**	**38**	**31**	**8**	**3**	**20**	**22**			

Table 6 List of field trips organised for BEWREMABI. From left to right, date, number of dive that date (0 dive means that trip has been cancelled for bad weather reason or no dive has been done due to other problems), number of Man Dive that day, number of scrapping sample on horizontal surface, number of scrapping sample on vertical surface, number of soft sediment sampled bags, miscellaneous sampling, number of cores done, number of fish trap deployed, number of Niskin bottle taken (turbidity measurement), number of CTD casts, number of Secchi disk measurements, umber of ADCP (Acoustic Doppler Current Profiler), number of Multibeam maps of wreck taken, video used, photo taken, name of the vessel used. BT for Blue Thistle, ST for Stream, ZL for Zeeleeuw, BE for Belgica, DS for Dive star. Wreck dived BOU for Bourrasque, BIR for Birkenfels, LST for LST420, LCT for LCT457, KLM for Kilmore, CAL for Callisto, SPE for Sperrbrecher 142, GDC for Garden City, DDN for Duc De Normandie and JHM for John Mahn.

3. Results

The repartition and extent of natural and artificial hard substrates on the BCS

The figure 2 presents the compiled information on the extent of natural hard substrates on the BCS (Houziaux, SPF research contract EV/36/45A).
The mean estimated dimensions for shipwrecks were 80.9 m in length and 11.4 m in width. The projected area of this mean wreck was 919.5 m^2 and its real surface was estimated to be between 3,677.8 m^2 and 6,436.2 m^2.
The 231 obstructions of the entire BCS totalised an area available for epibenthos colonization lying between 0.85 km^2 and 1.49 km^2. These estimations represented 0.025% and 0.043% of the surface of the BPNS.
19% of shipwrecks lay under the navigation routes and 23% at less than two nautical miles from harbours. 83% of the shipwrecks were at less than 30 km from the coast.
It means that generally, a wreck could be found at each node of a grid of 3.87 km side, but on the coastal zone, this grid would have had a size of 3.01 km and offshore a size of 6.64 km.

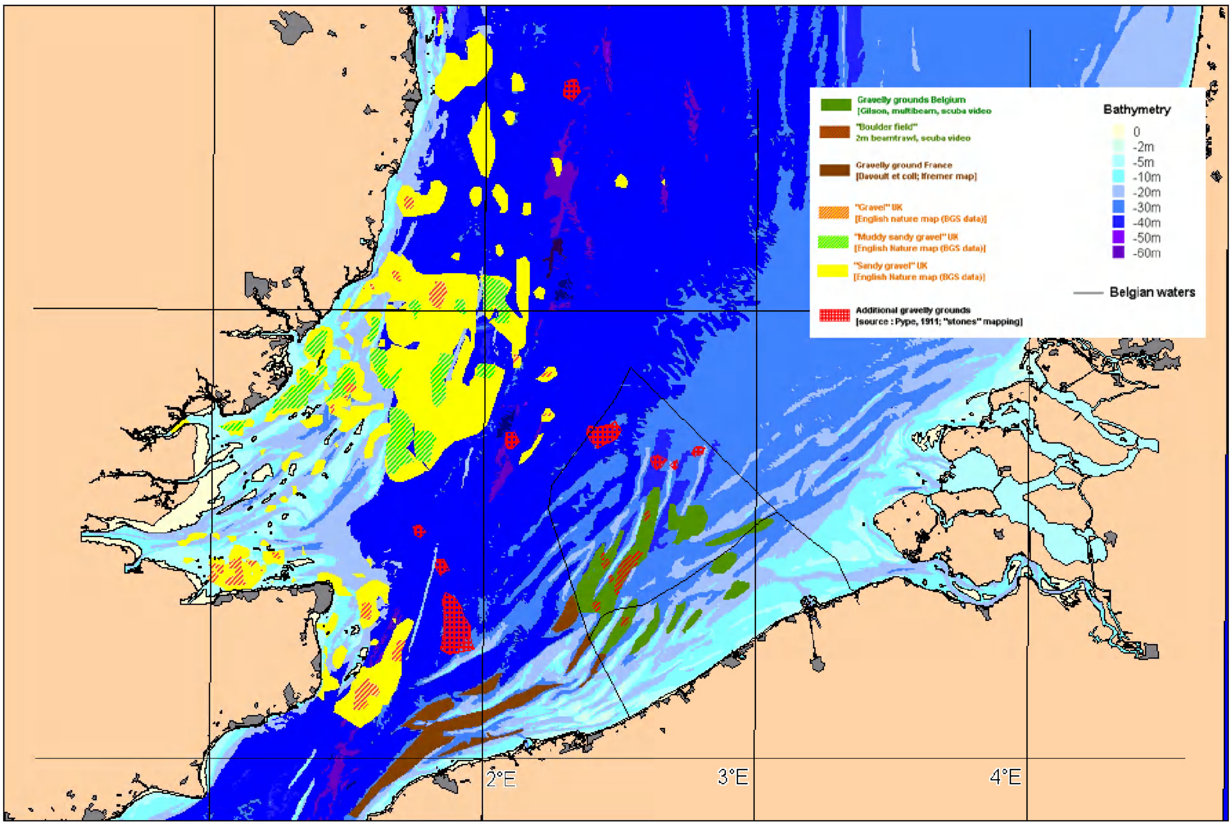


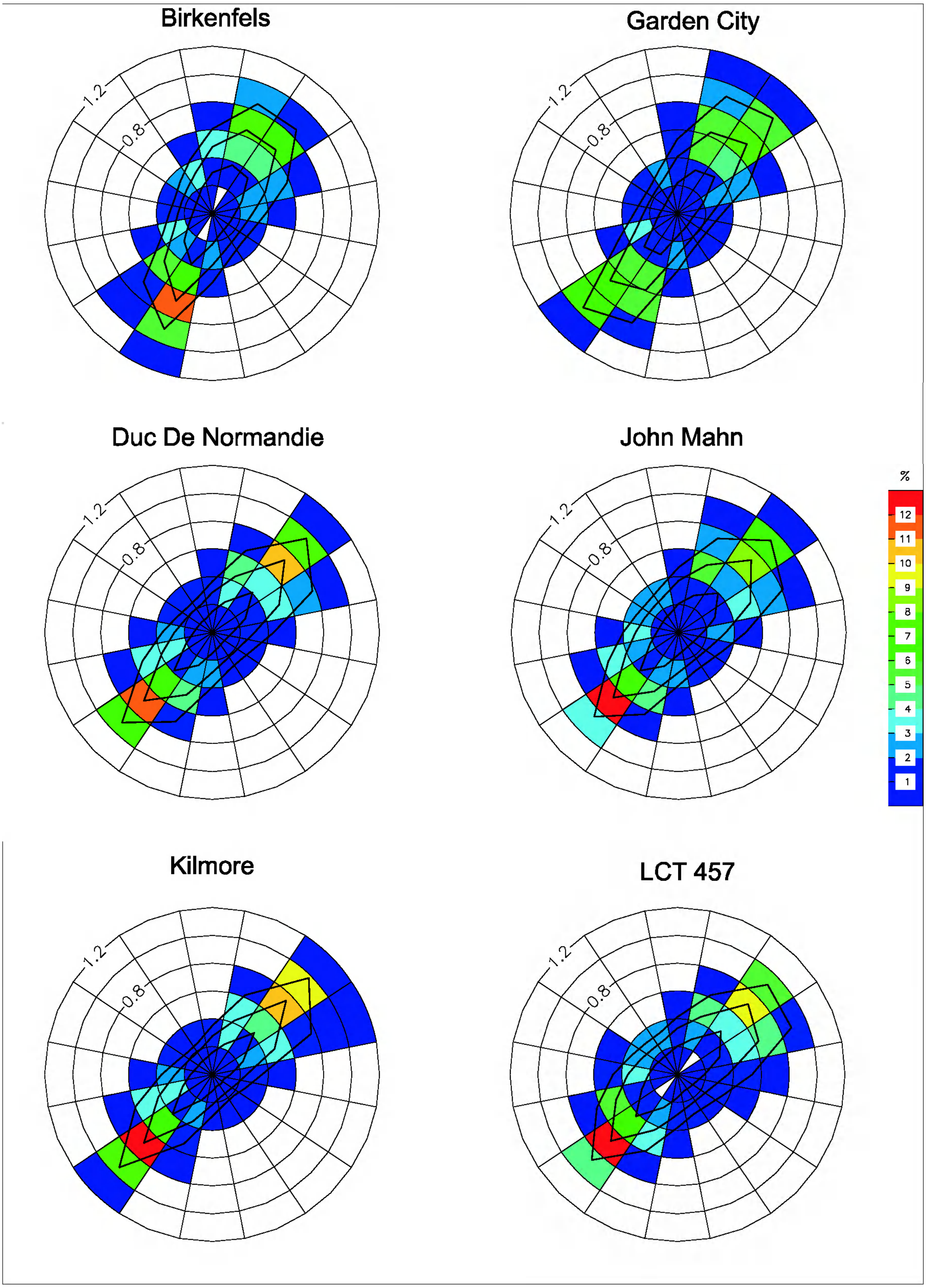
Figure 2. Suggestion of « gravel » distribution in the Southern Bight of the North Sea. Compilation of available geo-referenced data. Data sources: Jones et al., 2004 (BGS 1:250,000 seabed sediment map, British Geological Survey, ©NERC (IPR/37-32c)); Pype, 1911; personal communications from MINECO (M. Roche), RCMG (S. Deleu, V. Van Lancker) and "BEWREMABI" project; Gilson data; Augris et al., 1995; Davoult et al., 1988. Map compiled by J.S. Houziaux.

Abiotic environment

For each studied wreck, graphs and tables about abiotic data are provided in Annexe 3. The data obtained are presented in the following order when they are all available :

1. Graph of BMDC/IMERS data for salinity, temperature and turbidity
2. Elementary statistics of theses parameters.
3. Table of monthly means temperature and salinity from R/V Belgica underway data,
4. some CTD graphs
5. Graph of the total suspended matter derived from SeaWifs satellite data.
6. Graph of current velocity, direction…

A composite figure summarizing the current velocity and direction results obtained after modelisation is presented below as currents roses (Figure 3). North direction is upward. Three tidal ellipses have been added to each graph showing the 5 and 95 percentiles as well as the median of the current intensity. Concentric circles scale the intensity of the current. The color code indicates the percentage of the direction occurrence for a given class of velocity.
This representation offers a general view showing privileged direction as well as occurrence of these directions.


Birkenfels
Garden City
Duc De Normandie
John Mahn
Kilmore
LCT 457
1.2
0.8
%
12
11
10
9
8
7
6
5
4
3
2
1

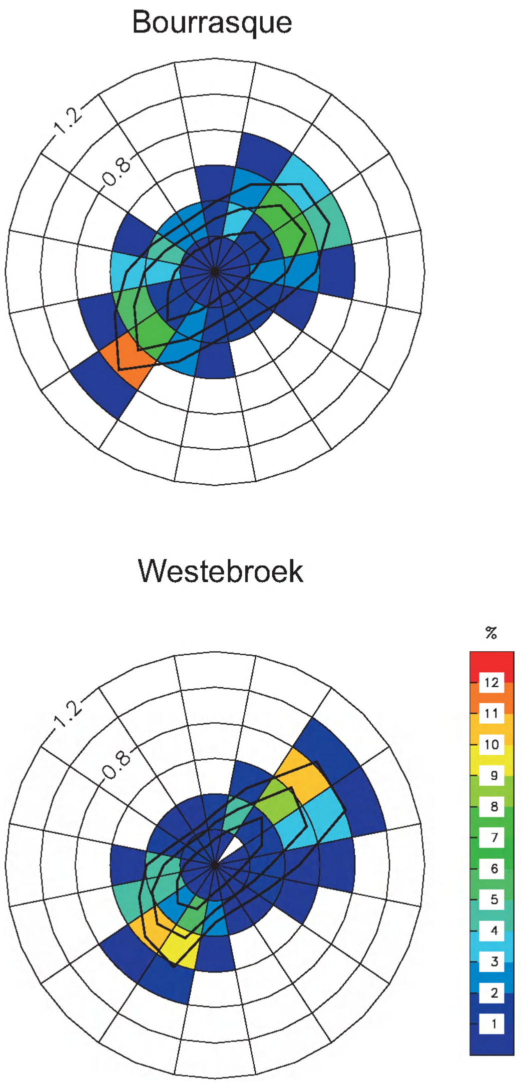


Figure 3: Current roses build from Mumm three-dimensional operational model results computed at the wreck position. Vertically averaged values.

If a North-East, SouthWest pattern of dominant current is clearly visible, no important difference in intensity is observed for these two privileged directions. In term of direction, the off-shore sites such as Birkenfels and Garden-City present direction oriented more to the North. This direction rotates to the East when approaching the shore as shown for the three shipwrecks Bourrasque, LST420 and Sperrbrecher 142 forming the shore cluster. The mid-distance cluster of shipwrecks formed by Kilmore, LCT457, John Mahn and Duc De Normandie presents intermediate results.
In term of intensity, the off-shore cluster of Birkenfels and Garden-City and the mid-distance cluster feature almost the same intensity maxima while the shore cluster composed of Bourrasque, LST420 and Sperrbrecher 142 presents weaker currents.

It could be observed that the maximum occurrence of direction seems to characterize South-West current for the mid-distance cluster of wrecks and for the Birkenfels but not for the Garden-City where no maximum occurrence direction can be highlighted.
For the shore cluster, South-West direction seems to be more frequent for Bourrasque while North-East prevails for LST420. Sperrbrecher 142 did not present difference in occurrence for the two directions of dominant current.

Suspended particulate matter

Data obtained from satellite images are summarized in the following tables (6-7)

tsm-modis	birkenfels	bourrasque	callisto	luc-normandi	garden city	Basilics	john mann	klm	lct	lst
jan-fev	6.06	15.29	6.23	7.80	6.24	27.25	7.30	7.77	9.65	20.94
mai-juin	5.23	5.90	5.26	5.55	5.96	7.07	5.55	5.57	5.84	7.08
aout-sept	5.31	7.29	5.33	5.81	5.73	9.66	5.77	5.99	6.72	11.44

Table 6: Averaged suspended particulate matter in mg/l (measured from Modis)

tsm-seawifs	birkenfels	bourrasque	callisto	luc-normandi	garden city	Basilics	john mann	klm	lct	lst
jan-fev	6.90	18.31	7.00	8.22	7.41	24.66	8.05	8.23	11.21	24.70
mai-juin	5.89	6.46	6.01	6.08	5.88	9.12	6.03	6.19	6.40	6.96
aout-sept	6.31	8.47	6.45	7.26	6.36	15.41	7.33	7.00	7.94	12.48

Table 7: Averaged suspended particulate matter in mg/l (measured from SeaWifs)

Information on suspended particulate matter can be obtained from Optical backstcatterance (OBS) data taken with sensor coupled to CTD. The data is presented on CTD profiles. These data can further be calibrated in Suspended particulate matter (SPM) units such as mg/l using the relation derived from Fettweis (2001) and illustrated in Figure 4

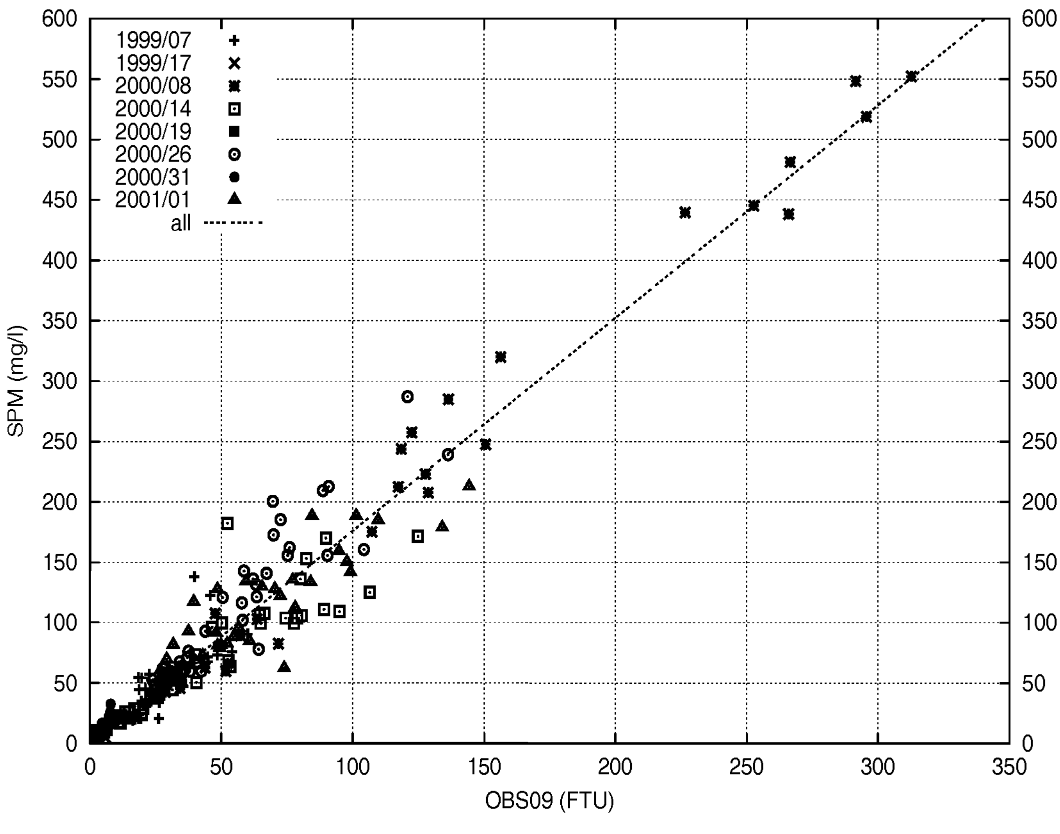


Figure 4: Relation between OBS measurement and Suspended particulate matter (SPM) from Fettweis 2001 (OBS09 for OBS sensor on SBE09 CTD probe)

Abiotic data: an overview

Analysis of available abiotic data graphs (see annexe 4) indicated that the different clusters (off-shore, intermediate and shore) of shipwrecks, introduced while presenting current result (see above) can also be observed:

- Particulate suspended matter presents a clear off-shore, in-shore gradient with more turbid water close to the coast. June and July proved to be less turbid than other periods of the year.

- For the temperature, warmer minimum is observed for the off-shore cluster (Birkenfels in March with 4.71°C) while coldest minimum is observed for the shore cluster (Sperrbrecher 142 -0.01°C in January). Intermediate cluster featured minimum of about 2 °C with a minimum for LCT457 at 1.25 °C for February. Maximum monthly mean temperature is always observed in August with a maximum of 22.53 °C for the shore cluster at Sperrbrecher 142 site. Minimum values observed for August are in the off-shore cluster with 20.01 °C for Birkenfels. Intermediate cluster sites are featuring values between the two extreme just mentioned. Inter-annual variability, presented here as the standard deviation on monthly mean values, is highest for Sperrbrecher 142 belonging to the shore cluster in January. Difference between minimum and maximum monthly mean values is maximal for Sperrbrecher 142 in February while minimum is observed for off-shore sites illustrating the different comportment of Belgian off-shore channel water and in-shore coastal water. Less variability and less extreme values of the subsurface temperature is confirmed for off-shore cluster than for in-shore shipwrecks.

- For salinity, maximum values of the monthly mean values range inside an interval of 1 around 34.5 while minimum features a wider interval of variation. Off-shore sites are presenting less variation than in-shores site. Birkenfels for instance, feature only very small variation around 35.0 while an in-shore site like Sperrebrecher presents wider variation around a value of 32. Standard deviation indicates also same variability as observed for temperature.

Meio-epifauna on shipwrecks

Results presented in this section are part of a manuscript entitled "Meiofauna communities on shipwrecks of the BCS" by Steyaert M., Lammertyn M., Vincx M. and Degraer S. (see annexe 1) dealing with the Kilmore (KLM) and Sperrbrecher 142 142 (SPR).

At all sampling occasions, amphipods were the most abundant taxon on both shipwrecks. The group of amphipods consisted mainly of juveniles of *Jassa herdmani* (pers. comm. V. Zintzen), a species also being an important representative of the macrofauna samples (Zintzen *et al.,*2006). Amphipods represented on average 45 % of the meiobenthic community; nematodes 42 %. Other meiobenthic taxa are copepods, cladocerans, cnidarians, oligochaetes, polychaetes, ostracods and tardigrades. On the higher taxon level, no statistical differences are demonstrated in between both shipwrecks, orientation of substrate or season.

Further discussion will focus on the nematode community. In total 42 nematode genera were reported, belonging to 22 different families. The most abundant family was the family Chromadoridae. No new genera were reported for the BCS.
Considering the total nematode densities, a statistical significant difference is found between shipwrecks ($p < 0.001$) and between seasons ($p > 0.05$), however not between surface orientations of the substrate. Highest abundances were detected in July and on the Kilmore wreck.

The TWINSPAN analyses revealed a separation of three well defined groups on the second division level (Figure 5): (1) samples of KLM in July, (2) samples of KLM in April, (3) samples of SPR in July. Exceptions to these groupings are two samples, i.e. KLM AH 1 and SPR JV 1. Remarkably, on the first division, all samples of Kilmore in July are separated from samples of the Sperrbrecher 142, and samples of Kilmore in April. Furthermore, the distinction of samples according to their orientation of the surface was only detected for the first TWIN group (KLM July).

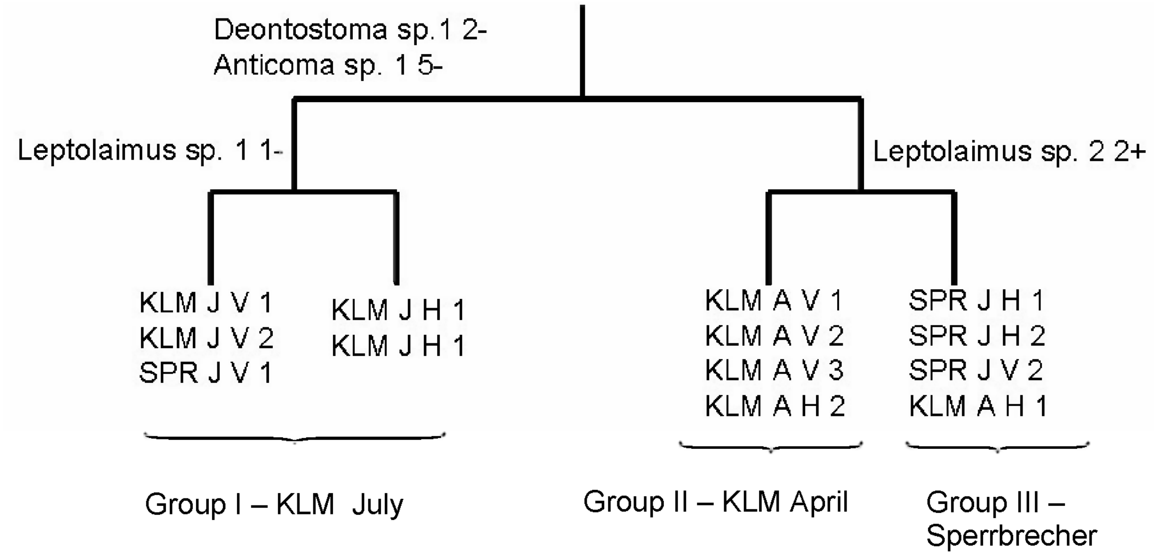


Figure 5: results of the TWINSPAN analyses

The total number of genera is 29, 34 and 29 for respectively the KLM July, the KLM April and the SPR July group. Relative small deviations in the dominance patterns of the three groups were found, with a prevailing dominance of four genera (Figure 6): *Anticoma, Chromadorella, Prochromadorella* and *Enoplus*. These four genera comprise 73 %, 61 % and 59 % of the nematode community in respectively the KLM July, the KLM April and the SPR July group.

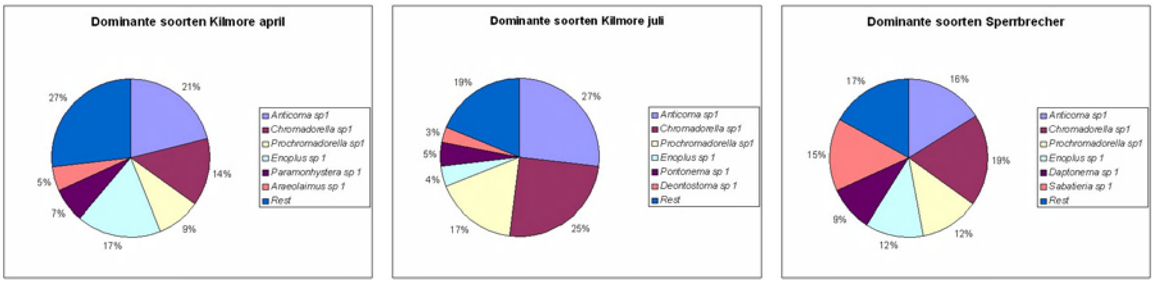


Figure 6. Dominant nematode genera for TWIN I, TWIN II and TWIN III

However, their absolute abundances differed significantly ($p < 0.05$) between the three groups. Taking into account all nematode genera, no significant differences were found in between the three groups.

Based on the feeding type classification of Wieser (1953), we found in all three groups a dominance of epistrate feeders (2A), a finding closely related to the dominant presence of *Chromadorella* and *Prochromadorella* (both 2A nematodes), in the three TWIN groups (Figure 7). The second most dominant feeding type were non-selective deposit feeders (1B) in the SPR July group and selective deposit feeders (1A) in the two KLM groups. No significant differences are demonstrated for relative abundances of feeding types.

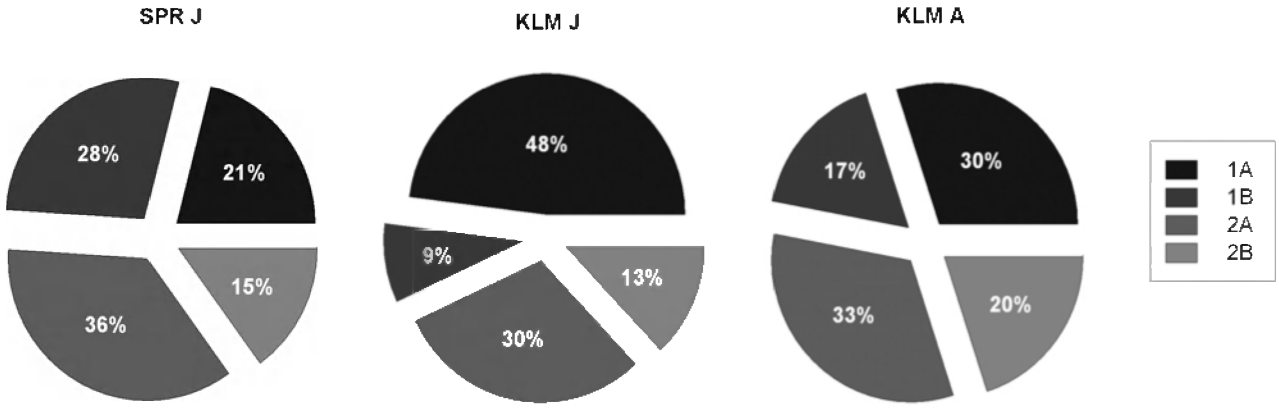


Figure 7. Feeding type distribution (Wieser, 1953) for TWIN I, TWIN II and TWIN III (1A: selective deposit feeders, 1B: non-selective deposit feeders, 2A: epistrate feeders, 2B: predators/omnivores)

Macrofauna of soft sediment around shipwrecks

Results presented in this section are part of a manuscript entitled "Effects of shipwrecks on the infauna of the nearby soft-sediments (BCS)." By V. de Maersschalck, M.Vincx & S. Degraer (see annexe 1)

Unique species

In total, 177 species were found in the BCS-samples and 87 species in the shipwreck-samples. Differences were found at species level between the shipwreck-samples and the BCS-samples. The crustaceans *Liocarcinus marmoreus* and *Photis longicaudata*, the echinoderm *Ophiothrix fragilis* and the polchaete *Tharyx killariensis* were species which were found only at the shipwreck-sites. The polychaetes *Lepidonotus squamatus*, *Lumbrineris tetraura*, *Serpula vermicularis* and *Sthenelais limicola*, the mollusc *Tritonia plebeia* and the crustaceans *Hippolyte longirostris*, *Inachus phalangium*, *Metopa alderi, Metopa borealis* and *Palaemon serratus* were rare species which were only found at the shipwreck-sites.

More than three shipwreck-samples were present to make a comparison between the BCS-samples and the shipwreck-samples for the *Nephtya cirrosa* community, the transitional species assemblage between the *N. cirrosa* and the *Ophelia limacina – Glycera lapidum* community and the *O. limacina – G. lapidum* community.

The BCS-samples and shipwreck-samples of the *N. cirrosa* community were not significantly different (ANOSIM: p=0.12), although six species had significant differences in abundance (Table 8). *Abra alba*, *Pagurus bernhardus* and *N. cirrosa* had higher abundances for the shipwreck-samples, while *Magelona johnstoni*, *Spiophanes bombyx* and *Bathyporeia elegans* occurred with higher abundances for the BCS-samples. *B. elegans* was not even present in the shipwreck-samples.

The samples of the transitional species assemblage between the *N. cirrosa* and the *O. limacina – G. lapidum* community had no significant differences between sample types (ANOSIM: p=0.05). Seven species had significantly different abundances between the BCS-samples and shipwreck-samples (Table 8). Significant higher abundances in the shipwreck-samples were found for *Jassa herdmani*, *N. cirrosa*, *Liocarcinus marmoreus*, *Crangon crangon* and *Atylus swammerdami*, while *Scoloplos armiger* had lower abundances and *O. limacina* did not even occur. *Liocarcinus marmoreus* was only present in the shipwreck-samples.

The samples of the *O. limacina – G. lapidum* community were significantly different between sample types (ANOSIM: p=0.01) and had significantly different abundances for seven species (Table 8). *Echinocyamus pusillus*, *Ophiura albida*, *Pisidia longicornis* had significantly higher abundances in the shipwreck-samples and *L. catena* only occurred in the shipwreck-samples. Significantly lower abundances in the shipwreck-samples were found for *Gastrosaccus spinifer* and a total absence for *Spio filiformis* and *Tellina pygmaeus*.

	Mann-Whitney U-test p-value	***Mean abundance BCS-samples***	***Mean abundance Shipwreck-samples***	***SIMPER Contribution %***
Nephtys cirrosa **community**				
Abra alba	<0.0001	0.40	83.85	6.94
Magelona johnstoni	0.0008	245.70	150.00	6.91
Spiophanes bombyx	0.0173	39.22	0.77	3.44
Pagurus bernhardus	0.0072	0.15	4.62	3.12
Bathyporeia elegans	0.0181	15.72	0.00	2.98
Nephtys cirrosa	0.0013	81.02	107.69	2.77
transitional species assemblage between the *N. cirrosa* community and the *O. limacina - G. lapidum* community				
Jassa herdmani	<0.0001	0.00	8.89	5.10
Scoloplos armiger	0.0039	19.32	1.48	5.09
Nephtys cirrosa	<0.0001	54.12	128.89	5.06
Ophelia limacina	<0.0001	12.46	0.00	4.91
Liocarcinus marmoreus	0.0002	0.00	13.70	4.87
Crangon crangon	0.0019	0.07	5.93	3.55
Atylus swammerdami	0.0159	0.15	4.81	2.81
Ophelia limacina - Glycera lapidum **community**				
Echinocyamus pusillus	<0.0001	7.65	1372.86	10.60
Gastrosaccus spinifer	0.0022	134.62	2.86	4.97
Ophiura albida	0.0000	3.20	77.14	4.63
Pseudocuma longicornis	0.0192	1.45	95.71	3.67
Lunatia catena	0.0018	0.00	28.57	3.47
Spio filiformis	0.0103	18.97	0.00	2.70
Tellina pygmaeus	0.0171	22.30	0.00	2.54

Table 8: Mann-Whitney U-test p-values (effect of sample type: BCS vs. shipwreck) concerning macrofaunal abundance (p<0.05 = significant value) per species per community or transitional species assemblage, with their mean abundance per sample type and the SIMPER contribution percentages from each species to the average dissimilarity between sample types.

SIMPER analysis indicated that the abundances of 47 species explained 90% of the variation between shipwreck-samples and surroundings-samples. Two-Way ANOVA confirmed that 18 species had significantly different abundances between the shipwreck-samples and the surroundings-samples (Table 9). A significant combined effect was also detected on the density of one of those species and a significant effect of communities or transitional species assemblages and a significant combined effect on the density was detected for five of those species. *Jassa herdmani*, *L. marmoreus*, *Abra alba*, *Atylus swammerdami*, *P. longicornis*, *P. bernhardus*, Actinaria sp. only occurred near shipwrecks. Significantly higher abundances near shipwrecks was found for *N. cirrossa* and *C. crangon*, while *S. armiger*, *S.bombyx*, *M. johnstoni* and *S. bonnieri* had significantly lower abundances near shipwrecks. *B. guilliamsoniana*, *Urothoe poseidonis*, *O. limacina*, *Pontocrates arenarius* and *Hesionura elongata* only occurred in the surroundings.

	ANOVA (effect shipwreck / surroundings) p-value	***Mean abundance shipwreck-samples***	***Mean abundance surroundings-samples***	***SIMPER Contribution %***
Scoloplos armiger	0.0037	8.95	52.91	5.91
Spiophanes bombyx *	0.0156	9.47	22.44	4.99
Magelona johnstoni **	0.0408	51.32	241.67	4.89
Bathyporeia guilliamsoniana	<0.0001	0.00	17.18	4.67
Jassa herdmani	0.0030	7.11	0.00	3.27
Nephtys cirrosa **	0.0001	124.21	62.95	3.23
Scolelepis bonnieri	0.0006	0.53	9.21	3.01
Liocarcinus marmoreus	0.0145	10.00	0.00	2.93
Crangon crangon	0.0123	6.32	0.44	2.75
Abra alba **	<0.0001	28.95	0.00	2.53
Atylus swammerdami	0.0078	6.58	0.00	2.35
Urothoe poseidonis **	0.0003	0.00	14.47	2.27
Pseudocuma longicornis	0.0259	8.95	0.00	1.69
Pagurus bernhardus	0.0036	2.37	0.00	1.64
Actinaria sp.	0.0372	3.16	0.00	1.48
Ophelia limacina **	0.0042	0.00	1.32	1.32
Pontocrates arenarius	0.0153	0.00	1.39	0.77
Hesionura elongata	0.0496	0.00	3.07	0.77

Table 9: ANOVA p-values (effect of sample type: shipwreck vs. surroundings, effect of communities or transitional species assemblages and combined effect not represented) concerning macrofaunal abundance ($p<0.05$ = significant value) per species, with their mean abundance per sample type and the SIMPER contribution percentages from each species to the average dissimilarity between sample types. *= significant combined effect; **= significant effect of communities or transitional species assemblages and significant combined effect

Physical habitat

All samples were characterized by medium sandy sediments with low mud content (Figure 8). The median grain size was significantly different between the communities or transitional species assemblages (two way ANOVA: $p<0.0001$), but there were no significant differences between the shipwreck-samples and the surroundings-samples (two way ANOVA: $p=0.51$). The variation due to the combined effect was not significant (two way ANOVA: $p=0.60$). At the Bourrasque and the Sigurd Faulbaums, a slightly higher mean median grain size was detected in the surroundings. The mud content was not significantly different between the communities or transitional species assemblages (two way ANOVA: $p=0.19$) and between the shipwreck-samples and the surroundings-samples (two way ANOVA: $p=0.62$). A combined effect was not detected (two way ANOVA: $p=0.06$). At the Bourrasque, a slightly higher mean mud content was found in the surroundings (0.16% vs. 0%), while the mean mud content was slightly higher at the Sigurd Faulbaums instead of in the surroundings (0.09% vs. 0.37%).

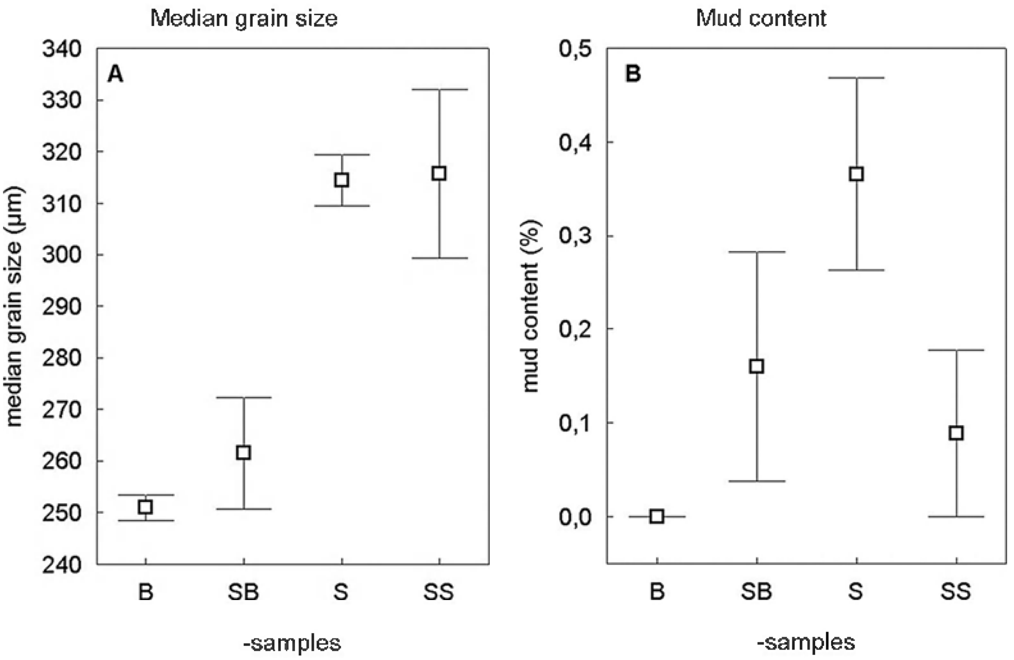


Figure 8: (A) plot of median grain size (µm) (mean ± SE), (B) plot of mud content (%)(mean ± SE). B: Bourrasque-samples; SB: surroundings of Bourrasque-samples; S: Sigurd Faulbaums-samples; SS: surroundings of Sigurd Faulbaums-samples.

Community structure

On the basis of the multivariate analyses, the shipwreck-samples were compared with the communities and transitional species assemblages between communities found at the BCS (Figure 9). Specific "shipwreck" communities were not detected. All samples of the Birkenfels and the Kilmore were closely related to the *Ophelia limacina – Glycera lapidum* community. Almost all Bourrasque-samples were adjacent to the BCS-samples belonging to the *Nephtys cirrosa* community. Two Bourrasque-samples and all samples of the Sigurd Faulbaums were related to the transitional species assemblage between the *N. cirrosa* and the *O.limacina – G. lapidum* community. The transitional species assemblage between the *Abra alba - Mysella bidentata* community and the *N. cirrosa* community was found in all samples of the LST 420. The only sample at the Sperrbrecher 142 belonged to the *A. alba – M. bidentata* community.

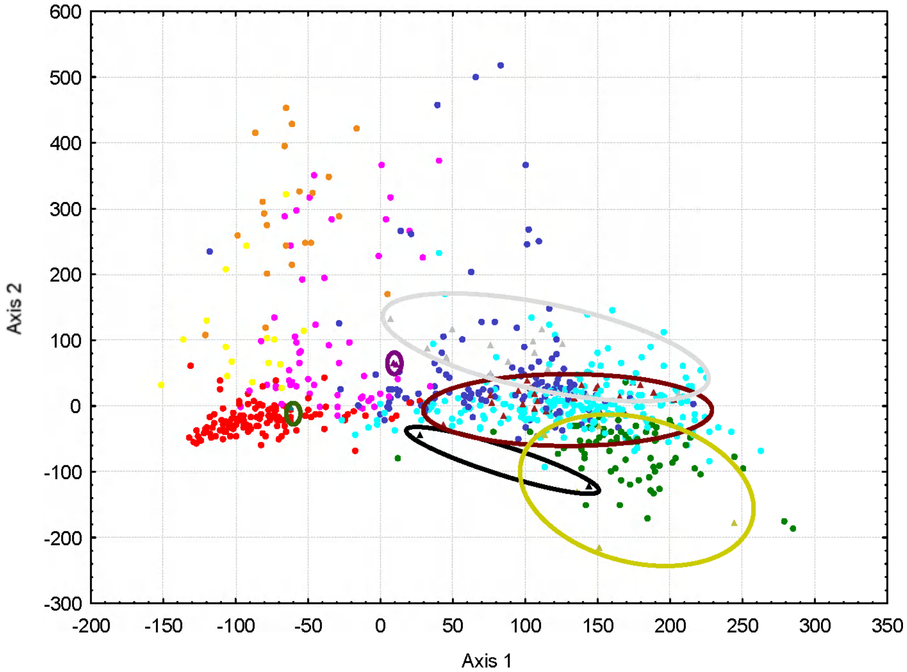


Figure 9: CA ordination plot along the first two axes. Position of the shipwreck-samples is indicated by the ellipses. ● *Macoma baltica* community; ● transitional species assemblage between the *M. baltica* community and the *Abra alba - Mysella. bidentata* community; ● *A. alba – M. bidentata* community; ● transitional species assemblage between the *A. alba - M. bidentata* community and the *N. cirrosa* community; ● *Nephtys cirrosa* community; ● transitional species assemblage between the *N. cirrosa* community and the *O. limacina - G. lapidum* community; ● *Ophelia limacina - Glycera lapidum* community; ▲ Birkenfels; ▲ Bourrasque; ▲ Kilmore; ▲ LST 420; ▲ Sperrbrecher 142; ▲ Sigurd Faulbaums.

Correspondence analysis (Figure 10) visualizes the differences in community organization between the shipwreck-samples and surroundings-samples. ANOSIM analysis indicated that these groups were significantly different (p=0.01).

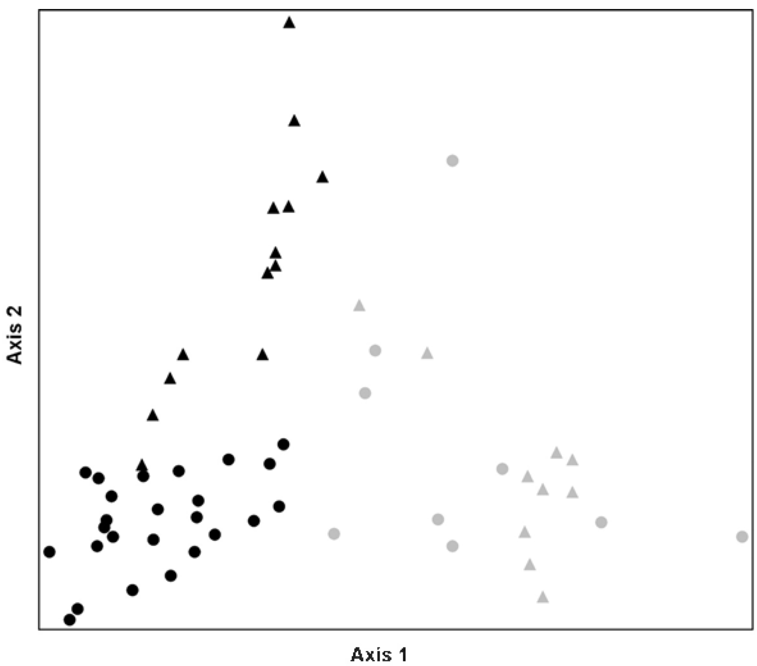


Figure 10: CA ordination plot along the first two axes.
Black = shipwreck-samples; grey = surroundings-samples. ▲= Bourrasque; ●= Sigurd Faulbaums.

Total density, species richness and N_1-diversity were compared between shipwreck-samples and surroundings-samples (Figure 11). Total density was significantly different between the shipwrecks (two way ANOVA: p=0.0002), but there were no significant differences between the shipwreck-samples and the surroundings-samples (two way ANOVA: p=0.35). The variation due to the combined effect was not significant (two way ANOVA: p=0.60). Mean density was lower at the Bourrasque in comparison with its surroundings (672 ind/m² vs. 866 ind/m²), while the mean density at the Sigurd Faulbaums was higher in comparison with its surroundings (257 ind/m² vs. 214 ind/m²). Species richness was significantly different between the shipwrecks (two way ANOVA: p=0.0007), but there were no significant differences between the shipwreck-samples and the surroundings-samples (two way ANOVA: p=0.18). A combined effect was not detected (two way ANOVA: p=0.64). Mean species richness for the Bourrasque and the Sigurd Faulbaums was slightly higher in the surroundings (resp. 9 spp/0.1m² vs. 10 spp/0.1m² and 6 spp/0.1m² vs. 7 spp/0.1m²). N_1-diversity was significantly different between the shipwrecks (two way ANOVA: p=0.004) and between the shipwreck-samples and the surroundings-samples (two way ANOVA: p=0.02), but a combined effect was not detected (two way ANOVA: p=0.75). Mean N_1-diversity for the Bourrasque and the Sigurd Faulbaums was slightly higher in the surroundings (resp. 5 vs. 7 and 4 vs. 5).

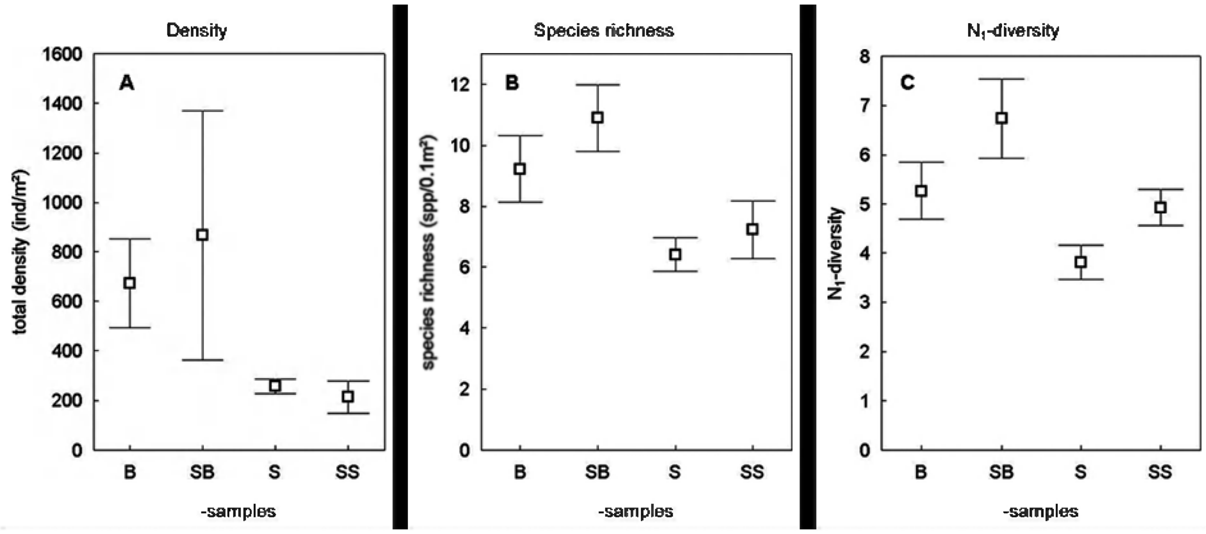


Figure 11: (A) plot of total density N (ind/m²) (mean±SE), (B) plot of species richness, S, expressed as number of species per sample (mean±SE), (C) plot of N_1-diversity (mean±SE). B: Bourrasque-samples; SB: surroundings of Bourrasque-samples; S: Sigurd Faulbaums-samples; SS: surroundings of Sigurd Faulbaums-samples.

Influence of distance.

Although the significant difference in median grain size (ANOVA: p<0.001), both the 1 m-samples as the 15 m-samples were characterized by medium sandy sediments with low mud content. The mean median grain size was significantly lower for the 15 m-samples (292 µm vs. 329 µm), while the mean mud content was similar (0.36%) (ANOVA: p=0.966) (Figure 12).

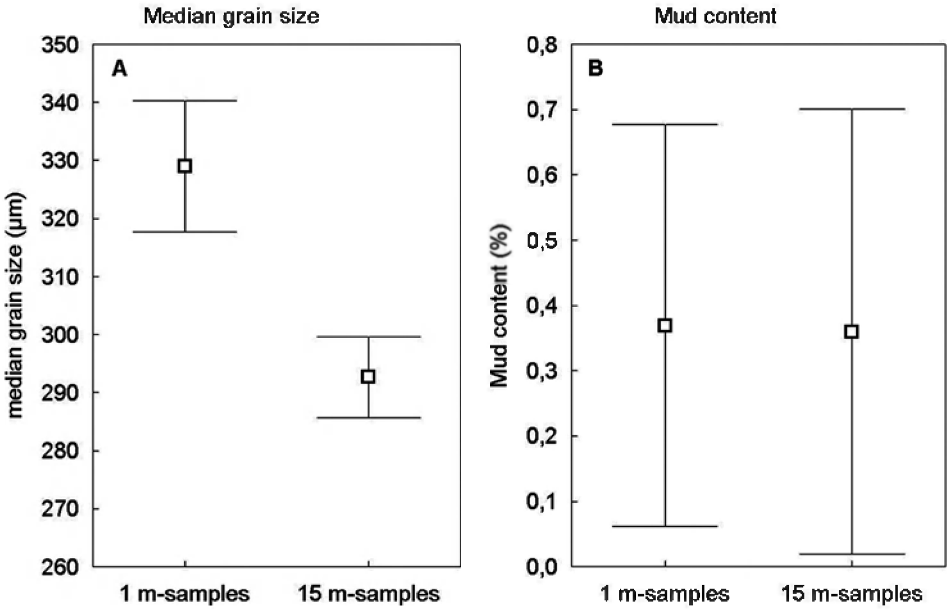


Figure 12: (A) plot of median grain size (µm) (mean±SE,), (B) plot of mud content (%) (mean±SE)

Correspondence analysis (Figure 13) visualizes the differences in community organization between the 1 m-samples and 15 m-samples. ANOSIM analysis indicated that these groups were significantly different (p=0.01).

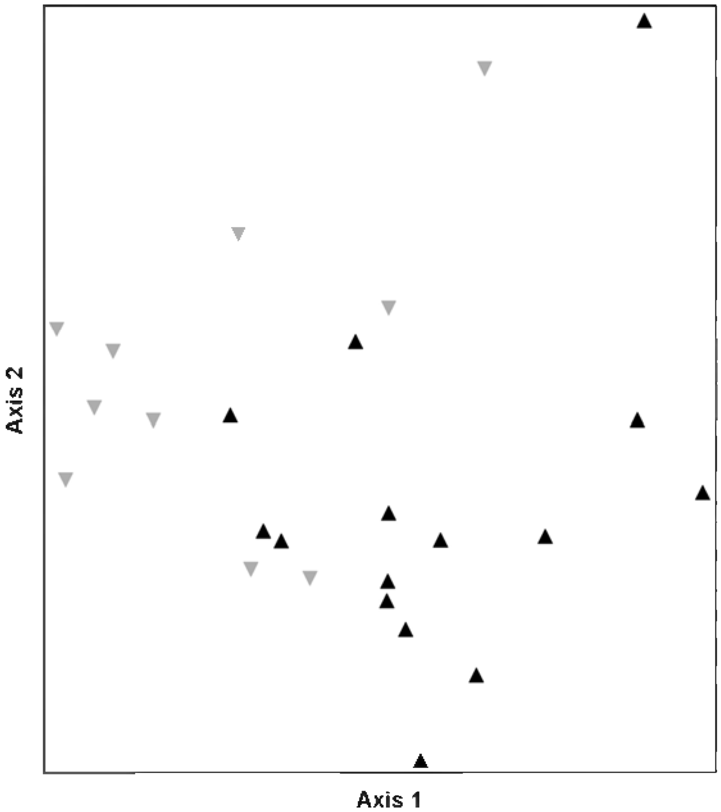


Figure 13: CA ordination plot along the first two axes. ▲ 1 m-samples; ▼ 15 m-samples.

Five species were significantly different between the 1 m-samples and 15 m-samples (Table 10). Significantly higher abundances in the 15 m-samples were found for *L. marmoreus*, *L. conchilega, C. crangon* and *A. swammerdami*, while *G. spinifer* was only present in the 1 m-samples.

	Mann-Whitney U-test p-value	*Mean abundance 1m-samples*	*Mean abundance 15m-samples*	*SIMPER Contribution %*
Liocarcinus marmoreus	0.0171	6.67	27.00	8.88
Lanice conchilega	0.0375	0.00	67.00	7.13
Crangon crangon	0.0401	3.33	11.00	6.86
Atylus swammerdami	0.0350	1.33	11.00	6.55
Gastrosaccus spinifer	0.0126	8.67	0.00	6.25

Table 10: Mann-Whitney U-test p-values (effect of sample type: 1 m vs. 15 m) concerning macrofaunal abundance ($p<0.05$ = significant value) per species, with their mean abundance per sample type and the SIMPER contribution percentages from each species to the average dissimilarity between sample types.

Density showed higher values in the 15 m-samples (mean N= 317 ind/m²) than in the 1 m-samples (mean N= 222 ind/m²), but those differences were not significant (ANOVA: p=0.188). Species richness (S) and N_1-diversity were very similar in 1 m-samples (resp. mean S= 6, mean N_1= 3.8) and 15 m-samples (resp. mean S= 7, mean N_1= 4.1) (ANOVA: S p=0.478, N_1 p=0.640) (Figure 14).

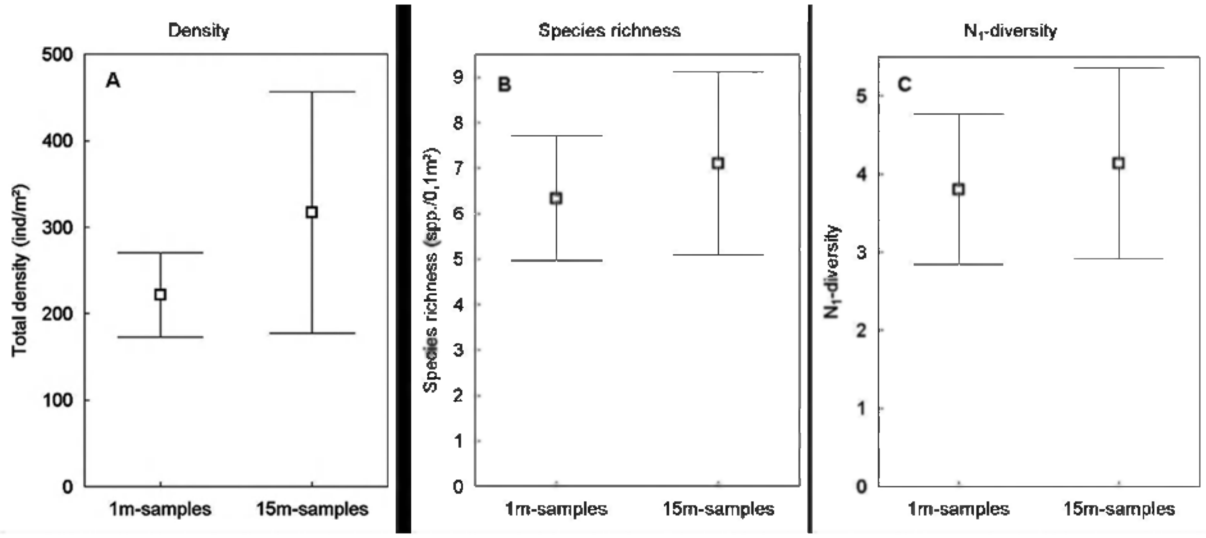


Figure 14: (A) plot of total density N (ind/m²), (B) plot of species richness, S, expressed as number of species per sample, (C) plot of N_1-diversity (mean–SE, mean+SE)

Macro-epifauna on shipwrecks

Results presented in this section are part of V. Zintzen PhD thesis (UCL-RBINS), more than 5 papers will be produced some are already published (see annexe 1).

The Annexe 5 presents the species richness and average density range for the different investigated sites between March and September (2001-2005). It totalizes 193 species. Another 9 species were only sampled between October and February (Annexe 6) and 22 more species were observed *in situ* or after examination of digital pictures (Annexe 7). The current pooled species richness for Belgian shipwrecks is then 224 sp from which 46 are new to Belgian fauna.

Identity of shipwrecks macro-epifauna

General trend

In both soft and hard substrates, polychaetes, crustaceans and molluscs were the dominant higher taxa in terms of number of species (Figure 15). For hard substrates, 71% of the species belonged to these three taxa and 94% for soft sediments. No algae were found. Some groups not recorded from soft sediments were well represented in hard substrates (bryozoans, poriferans, nemertineans and sipunculans). On average, 70% of available hard substrate is covered by epifauna.

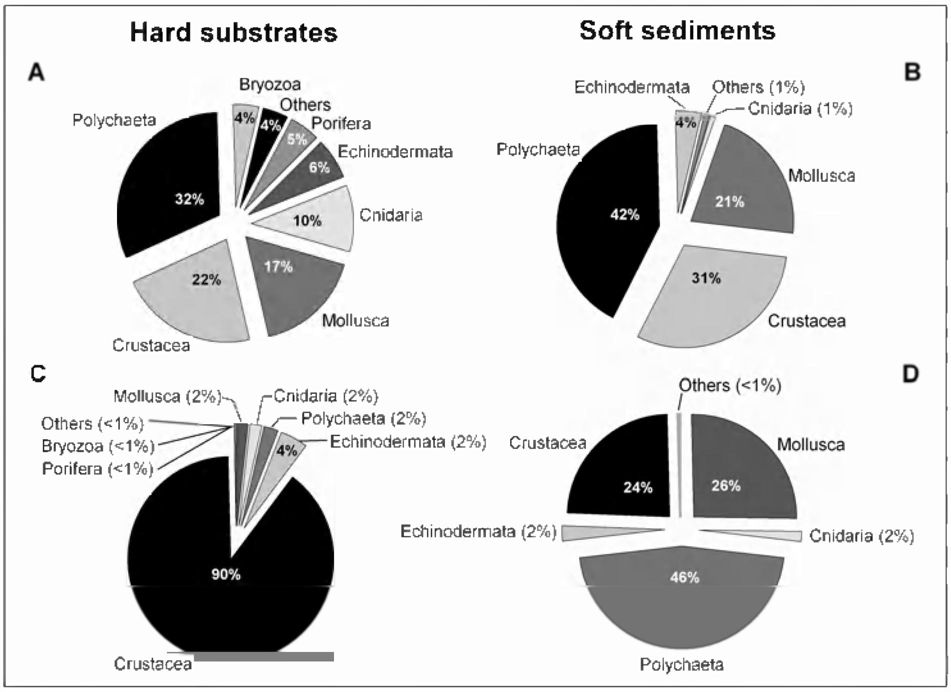


Figure 15. Species richness distribution (A and B) and abundance (C and D) on hard substrates and soft sediments. Others: Chordata (Tunicata), Nemertina and Sipuncula.

The abundance of specimens on hard substrates was dominated by crustaceans (90%, mainly the amphipod *Jassa herdmani*), while a more balanced situation prevailed on soft sediments where again polychaetes (46%) dominated followed by an equal proportion of molluscs (26%) and crustaceans (24%). The difference in evenness of the two distributions was clearly illustrated by the rank/abundance plots (Figure16).

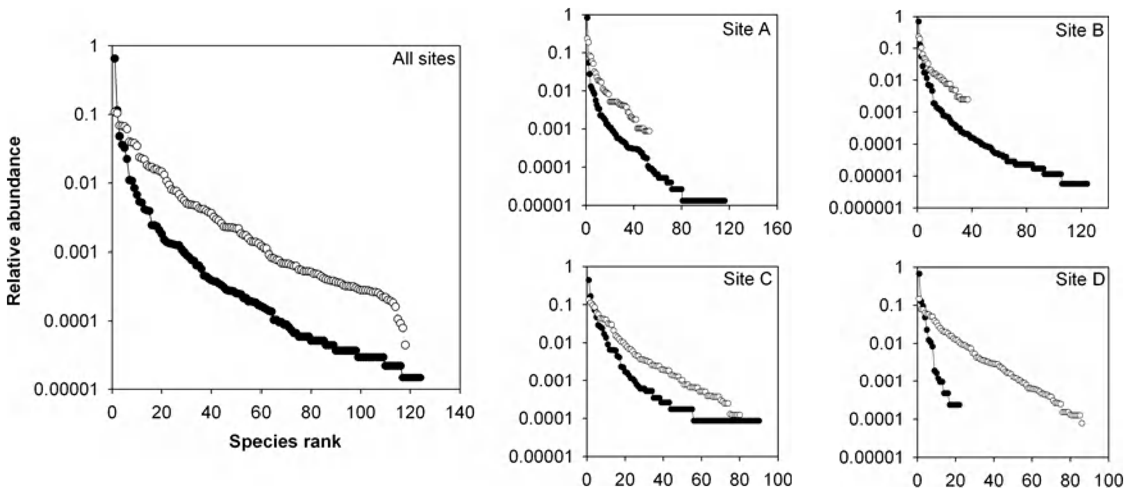


Figure 16. Rank/abundance plot based on count of species on hard substrates (●) and selected soft sediments (○) around hard substrate sites (distance: circle of 5 nautical miles, number of samples: site A-Birkenfels (38), B -Kilmore (14), C-Bourrasque (90), D-Sperrbrecher 142 (118)).

On hard substrates, a few species had a high abundance while the distribution of abundance classes was more uniform on soft sediments. The abundance pattern of species among the two substrates was different, even when omitting the most abundant species (*J. herdmani*) from the hard substrates dataset (Kolmogorov-Smirnov test, $p<0.001$). The abundance of individuals was on average 25 times higher on shipwrecks than on soft sediments (Table 11). The maximum abundance observed on shipwrecks was over 280,000 ind.m^{-2} and 1,076 ind.m^{-2} for soft sediments.

	Species richness			Abundance (ind.m^{-2})		
	Mean (± s.d.)	Min	Max	Mean (± s.d.)	Min	Max
Soft sediments	11 ± 9	1	50	1076 ± 2442	8	26,508
Hard substrates (HS)	24 ± 12	2	52	27,014 ± 55,748	44	281,172
HS – Birkenfels site	24 ± 8	11	49	27,628 ± 55,206	966	240,182
HS – Kilmore site	36 ± 10	7	52	49,030 ± 73,094	256	281,172
HS – Bourrasque site	13 ± 8	2	39	2,659 ± 4,165	44	18,774
HS – Sperrbrecher 142 site	10 ± 5	3	16	5,540 ± 3,743	1,320	10,432

Table 11. Species richness and abundance of soft sediment and hard substrate samples

Combined species richness of both habitats was 220. Although not directly comparable, the macrofauna species richness of samples for soft sediments ranged from 1 to 50 (average: 11 sp.$sample^{-1}$) and from 2 to 52 (average 24 sp.$sample^{-1}$) for hard substrates (Table 11). Comparison of species richness was realized through species accumulation curves (Figure 17). As well for hard substrates as for soft sediments, these curves showed no sign of approaching asymptotic value and consequently had to be seen as minimum estimates. The chao2 estimate of true species richness for hard substrates peaked at 261 ± 20 sp. and at 224 ± 20 sp. for soft sediments at the respective maximal sampling intensity. Again, none of these estimates are close to reach an asymptote. The mean number of species (± s.d.) observed per square meter was 106 ± 6 and 44 ± 5 for hard substrates and soft sediments, respectively. However, if we look at species richness as a function of accumulated number of individuals, we observe that species richness on soft sediments is higher than on hard substrates. For example, at a sampling effort of 50,000 individuals, Chao2 for soft sediments is 184 ± 14 sp and 165 ± 20 for hard substrates.

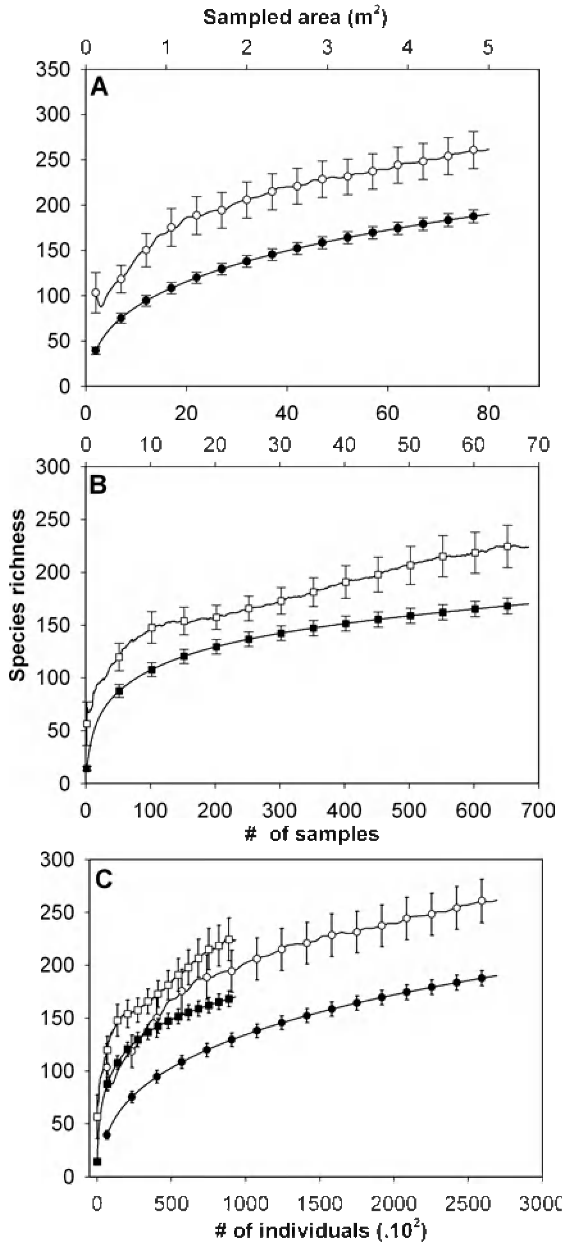


Figure 17. Species accumulation curves for the entire datasets. Estimators of the species richness are the total number of all species (Sobs, ● and ■) and the Chao2 estimator of true richness (○ and □). Results are mean ± s.d. for a selection of points based on 50 randomizations (without replacement). (A) Accumulated number of samples on hard substrates. (B) Accumulated number of samples on soft sediments (square symbol). (C) Accumulated number of individuals on hard substrate (○ and ●) and soft sediments (□ and ■).

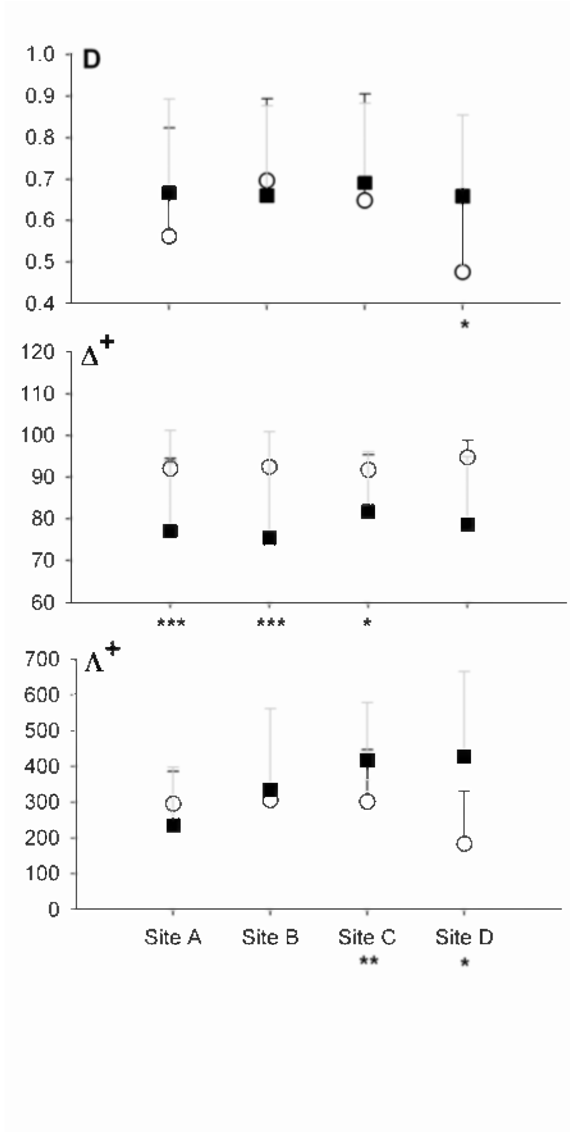


Figure 18. Diversity index comparison of hard substrate (○) with selected soft sediment (■) samples around hard substrates (distance: circle of 5 nautical miles, number of samples: site A-Birkenfels: 38, B-Kilmore: 14, C-Bourrasque:90, D-Sperrbrecher 142: 118). Values are mean values + standard error. D is the Simpson index; Δ+ is the average taxonomic distinctness; Λ+ is the variation in taxonomic distinctness. Significant difference between means tested with Monte Carlo permutation (999 randomizations) (* p<0.05, ** p<0.01, *** p<0.001).

Univariate analysis

The two data sets shared 23 species (9.6% of the total number of species). Most of them were polychaetes (54%), molluscs (22%) and crustaceans (13%). The occurrence of species from both habitats showed an inverse correlation (Spearman's and Kendall rank correlation with p<0,05): occurrence of shared species which was high on one habitat was generally low on the other habitat.

There was no obvious trend in the Simpson index (Figure 18). Only its value for site D (Sperrbrecher 142) was significantly under the one of the surrounding sediments. The average taxonomic diversity was significantly higher on all the hard substrate sites than on the surrounding soft sediments (Figure 18). Site D had a low value of variation in taxonomic distinctness and inversely the soft sediments close to the coasts displayed a rather high value meaning that their assemblages were dominated by many species belonging to the same low taxonomic level (Figure 18).

Multivariate analysis

Multidimensional scaling and clustering (not shown) based on Bray-Curtis similarity index from fourth root transformed abundances showed a clear differentiation between samples originating from soft sediments and from hard substrates (Figure 19,A). This differentiation was further confirmed by the result of the ANOSIM analysis (global R: 0.738, p<0.001). The pair-wise comparison of ANOSIM was significant (p<0.001) for each group except for Bourrasque with Sperrbrecher 142 (p=0.103). Apart from these two sites that ANOSIM test did not differentiate, all hard substrate sites were different from soft sediments assemblages and from each other. The MDS based on the taxonomic similarity also differentiated the soft sediment and hard substrate samples and was confirmed by the ANOSIM analysis (global R: 0.831, p<0.001) (Figure 19,B).

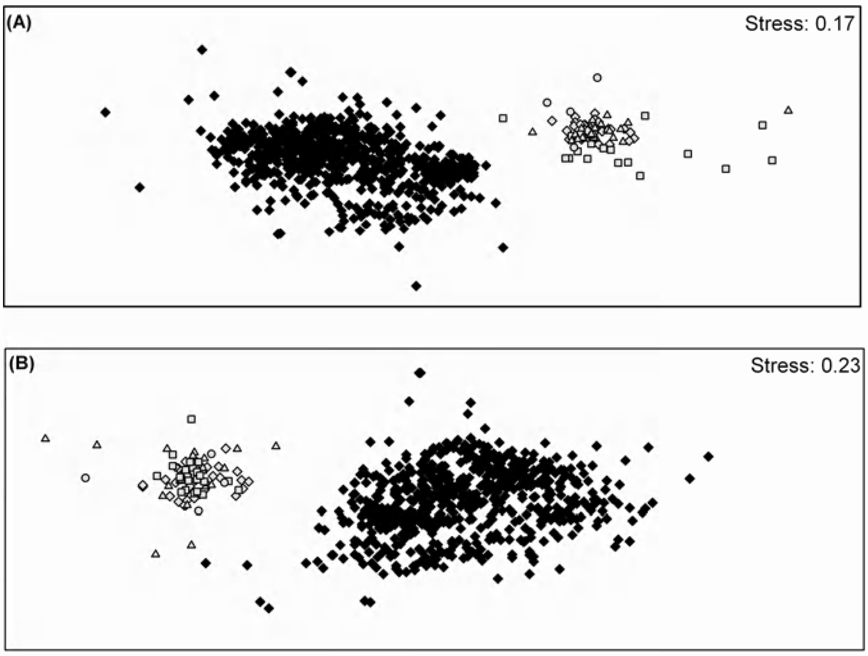


Figure 19. Multidimensional scaling ordination of macrobenthos samples. (A) Bray-Curtis similarity index based on fourth root transformed abundance data. (B) taxonomic dissimilarity. ♦ : soft sediments, ◊ : hard substrates (HS) Birkenfels, Δ : HS Kilmore, □ : HS Bourrasque, ○ : HS Sperrbrecher 142.

Biomass

The mean biomass for the hard substrates was 628 g AFDW.m^{-2} with site values ranging from 195 to 1174 g.m^{-2} (Figure 20). Minimal sample biomass was 30 g.m^{-2} and maximal value was 3,148 g.m^{-2}, both on Sperrbrecher 142 (site D). This last sample was exclusively composed of *Metridium senile*. There was an apparent decreasing average biomass from coastal to offshore sites. The soft sediment samples had an average biomass of 7.4 g.m^{-2}. Minimal and maximal biomass were 0.02 g.m^{-2} and 65 g.m^{-2}, respectively.

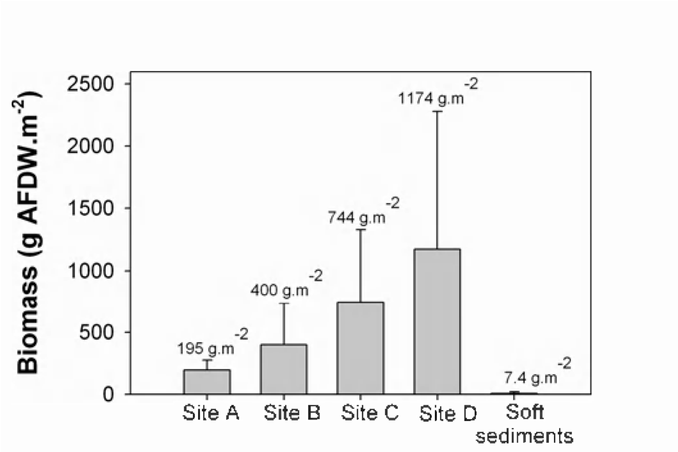


Figure 20. Biomass on hard substrates (sites A to D) and soft sediments. Site A: Birkenfels, B: Kilmore, C: Bourrasque, D: Sperrbrecher 142.

Trophic structure

Except for deposit feeders, all the other trophic groups were significantly different between soft sediments and hard substrates (Mann-Whitney U test, figure 21). The general pattern for hard substrates was clearly dominated by suspension feeders, even when suppressing the effect of the dominant species *J. herdmani*, which belongs to this trophic category. This dominance was mainly due to amphipods such as *Phtisica marina*, *Caprella tuberculata* and *Monocorophium sextonae*, to the anomour *Pisidia longicornis*, and to actiniarian species (Table 12). The second most important trophic group were predators. These were mainly represented by polychaetes such as *Phyllodoce mucosa*, *Harmothoe* spp., *Pholoe inornata*, *Lepidonotus squamatus* and other members of Phyllodocidae, Nereidae and Syllidae families. Other abundant predators were nemertean, pycnogonid and nudibranch species. Sand licker feeding type was absent from hard substrates and subsurface deposit feeder was represented by only two species (*Pectinaria koreni* and *Cumacea* sp.). In general, each hard substrate site individually held the same type of trophic organization. There was no such a clear-cut dominance of one feeding group for soft sediments macrofauna.

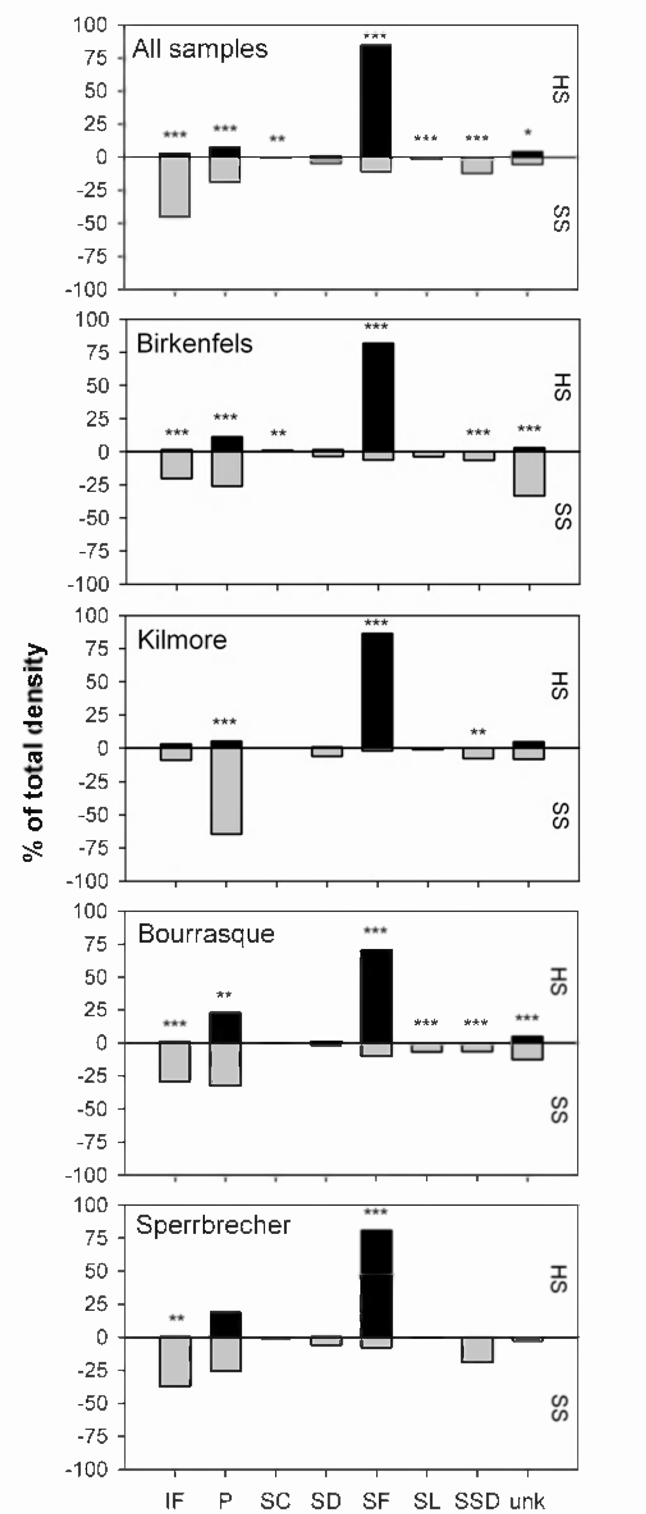


Figure 21. Contribution of the different trophic groups to total density. The soft sediment samples selected around hard substrate sites are within a circle of 5 nautical miles. On hard substrates, the dominant species *Jassa herdmani* is excluded from calculation. IF: interface feeder, P: predator, SC: scavenger, SD: deposit feeder, SF: suspension feeder, SL: sand licker, SSD: subsurface deposit feeder, Unk: unknown type. *** $p<0.001$, ** $p<0.01$, * $p<0.05$ (significance level of a Mann-Whitney U test).

Spatial variability

In the following section, the nine shipwrecks will be categorized into coastal (Bourrasque, LST420), offshore (Birkenfels, Callisto, Garden City) and intermediate sites (Kilmore, John, Mahn, Duc de Normandie, LCT457) according to their distance from the coast.

General cover and community analysis of the photographic transects

Generally, the percentage of surface not covered by epifauna for the 9 shipwreck sites was 30%. Epifaunal cover was generally high for the sites at an intermediate distance from the coast, medium to high for offshore sites and low for coastal sites (Figure 22). The Birkenfels showed the lowest epifaunal growth with 70% uncovered, bare surface. Due to poor visibility conditions, a limited set of features was recognizable from the underwater photography. The main taxa that were identifiable were: *Tubularia* spp. (a mixture of *T. indivisa* and *T. larynx*), *Sagartia* sp., *Asterias rubens*, *Metridium senile* and *Diadumene cincta* (Figure 22). Less common taxa identified were: *Actinothoe sphyrodeta*, *Cancer pagurus*, *Dendronotus frondosus*, *Diplosoma* sp., unidentified Porifera, *Haliclona* sp., *Jassa* tubes, *Nassarius* sp., *Necora puber*, *Nemertesia antennina*, *Ophiothrix fragilis*, *Pagurus* sp., *Pomatoceros triqueter*, *Sycon* sp. and *Urticina felina*. No macroalgae were recorded.

Coastal shipwrecks had 52% of their surface covered by *M. senile* and 29% covered by a mixture of *T. indivisa* - *T. larynx* - *J. herdmani* (if excluding bare surface). The other sites were on average covered at 81% by *T.* indivisa - *J. herdmani*.

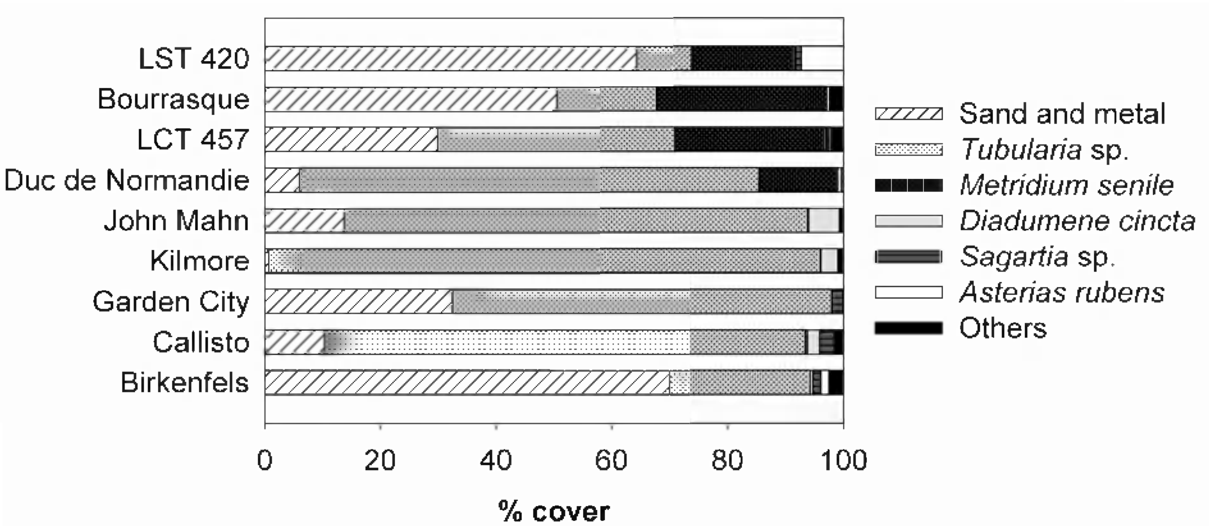


Figure 22. Mean percentage cover of epifauna on the shipwrecks estimated from photographic quadrats. Others: *Actinothoe sphyrodeta*, *Cancer pagurus*, *Dendronotus frondosus*, *Diplosoma sp*, *Porifera*, *Haliclona sp*, Jassa tubes, *Nassarius sp*, *Necora puber*, *Nemertesia antennina*, *Ophiotrix fragilis*, Paguridae, *Pomatoceros triqueter*, *Sycon ciliatum*, *Urticina felina*, fishing lines/net and unidentified feature.

Univariate analysis of the Tubularia *sp. community*

A total of 90 species were recorded. Species diversity ranged from 13 to 40 species per site with a mean value of 29 species (Figure 23). The species number (N_0) was significantly lower at the Bourrasque and LST 420 shipwrecks ($p < 0.05$ and figure 10). The Simpson index (D), the average taxonomic distinctness (Δ^+) and the variation in taxonomic distinctness (Λ^+) showed little variations between sites. The following significant differences were found ($p < 0.05$): LST 420 and Bourrasque for D, Kilmore and Bourrasque for Δ^+, Duc de Normandie and Bourrasque for Δ^+ and for Λ^+.

The dominant species were generally observed in the majority of the sites (Table 12). The amphipods accounted for 94% of the specimens in our samples. A large fraction (89%) of these amphipods were *Jassa herdmani* which had an average density of 116,997 ind.m^{-2} and a maximal density of 180,000 ind.m^{-2} in one Kilmore sample. Other caprellid species and species of the genus *Stenothoe* were also abundant. Four polychaetes were numerically abundant (*Phyllodoce mucosa*, *Harmothoe* spp., *Eulalia viridis* and *Sabellaria spinulosa*). Echinoderms were represented by three species that were abundant (*Ophiothrix fragilis*, juveniles of *Asterias rubens* and *Amphipholis squamata*). The nemertean *Oerstedia dorsalis* was reported on all sites.

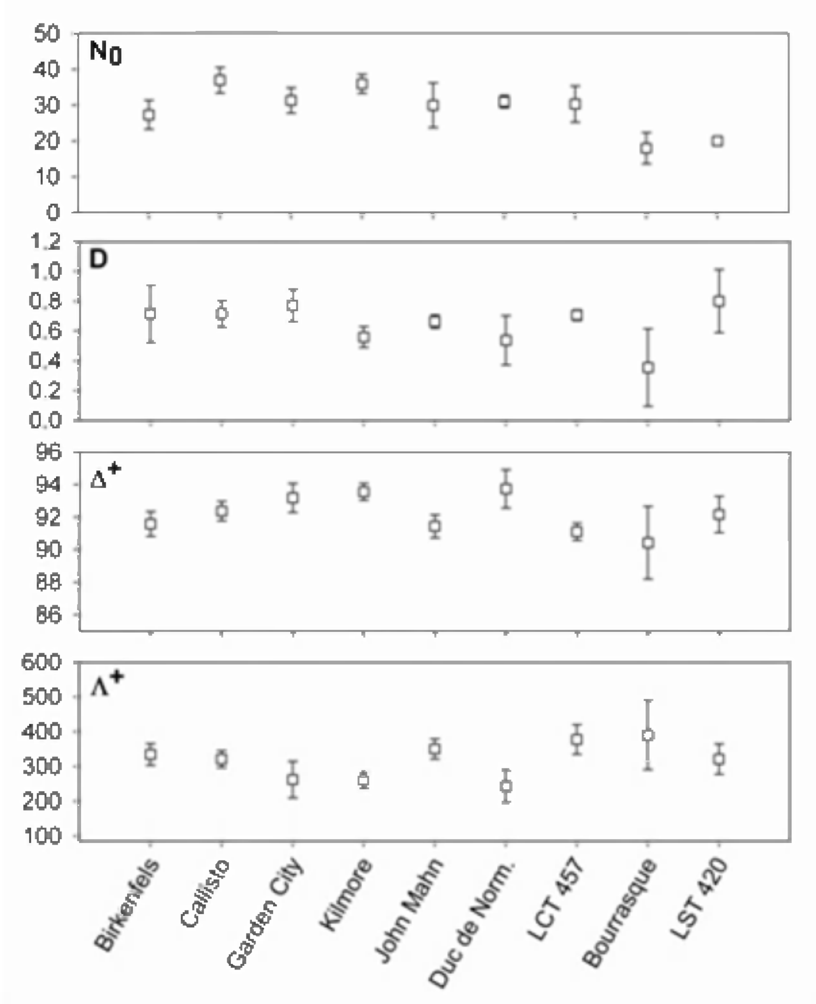


Figure 23. Mean number of species (N_0), Simpson index (D), taxonomic distinctness (Δ^+) and variation in taxonomic distinctness (Λ^+) for each shipwreck site (N=3, ± sd).

Species		Global mean abundance (ind.m^{-2})	Dispersion (%site)	Local mean abundance (ind.m^{-2})	Site of maximal mean abundance
Jassa herdmani	CRU	63,029	100	116,997	Kilmore
Caprella tuberculata	CRU	3,219	78	22,677	Kilmore
Phtisica marina	CRU	1,343	100	4,315	John Mahn
Stenothoe valida	CRU	1,253	89	4,192	LCT457
Pisidia longicornis	CRU	950	100	1,909	Callisto
Ophiothrix fragilis	ECH	831	100	1,269	Garden City
Stenothoe monoculoides	CRU	823	89	3,643	Kilmore
Phyllodoce mucosa	POL	804	89	6,533	LCT457
Mytilus edulis	MOL	516	100	2,971	Kilmore
Asterias rubens juv.	ECH	363	67	885	LCT457
Actiniaria	CNI	345	100	581	Duc de Nor.
Stenothoe marina	CRU	334	100	731	LCT457
Monocorophium sextonae	CRU	299	89	1,435	LCT457
Metopa alderi	CRU	245	89	944	John Mahn
Harmothoe spp.	POL	152	100	427	John Mahn
Oerstedia dorsalis	NEM	141	100	427	LST420
Sabellaria spinulosa	POL	121	89	555	Callisto
Amphipholis squamata	ECH	107	78	624	Kilmore
Eulalia viridis	POL	74	78	475	LCT57
Pilumnus hirtellus	CRU	63	89	144	Callisto

Table 12: Dispersion (site occupation), global (all sites) and maximal local mean abundances of the 20 most dominant taxa. CRU: Crustacea, CNI: Cnidaria, ECH: Echinodermata, MOL: Mollusca, NEM: Nemertinata, POL: Polychaeta,

Spatial variation of* Tubularia *sp. community

The mean biomass of the *Tubularia* sp. community from shipwrecks was 288 g AFDW.m^{-2} (Figure 24). This value does not include the biomass from tubes built by amphipods (*Jassa herdmani*). These tubes were made of organic material collected from surrounding waters. On average, the biomass accumulated in these tubes was 92 g AFDW.m^{-2}. The hydrozoans *Tubularia indivisa* and *Tubularia larynx* accounted for 69% of the recorded biomass. Crustaceans, mainly amphipods species and the anomouran decapod *Pisidia longicornis*, constituted another 21% of the recorded biomass. Echinoderms, mainly *Ophiothrix fragilis*, represented 4% of the total biomass. Three sites, the Kilmore, the LCT 457 and the John Mahn shared high biomass values of 584, 474 and 471 g AFDW.m^{-2}, respectively. Lowest biomass values were found at the LST 420 and Bourrasque (55 and 150 g AFDW.m^{-2}).

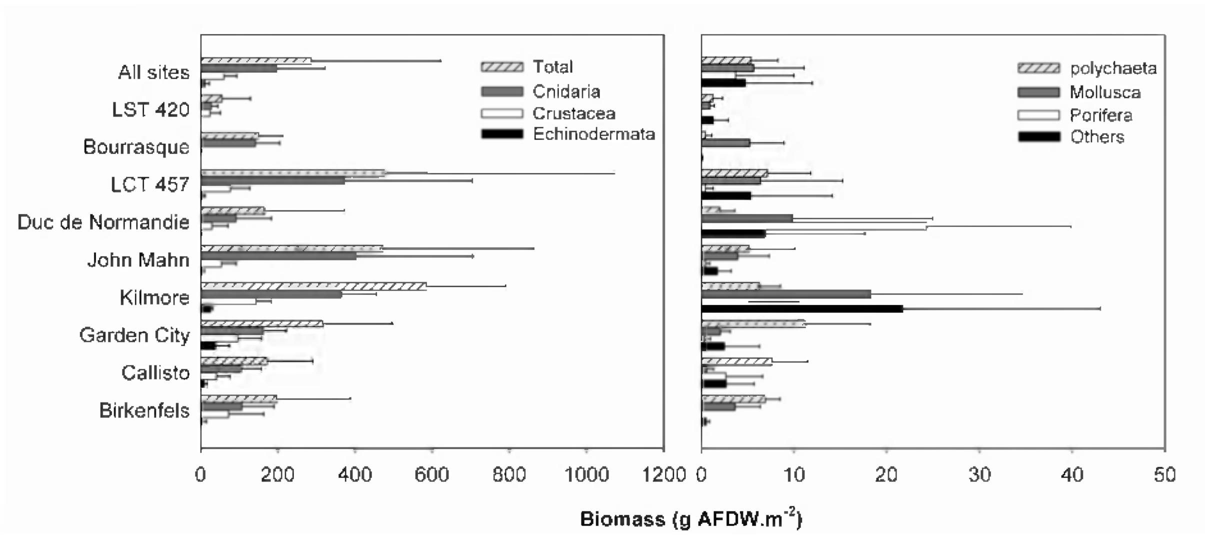


Figure 24. Mean biomass values (N=3, + s.d.) of shipwrecks sites for main taxonomic groups. Others: Tunicata, Nemertea, Bryozoa and Turbellaria.

The fauna of the Duc de Normandie was typified by a low biomass of polychaetes and Cnidaria combined with a relative high biomass of sponges.
The Bourrasque (site H) and LST 420 (site I) were found to clearly differ from the other shipwrecks in the ordination plane (Figure 25,i). Ordination and clustering identified two additional groups (Figure 25,ii & iii). The Kilmore (site D), LCT 457 (site G) and John Mahn (site F) comprised a first group. A second group associated the Birkenfels (site B), Callisto (site C) and Garden City (site A). One site, the Duc de Normandie (site E) did not have clear affinities with the other shipwrecks. These groupings were further confirmed by an ANOSIM test (global R: 0.823, $p < 0.001$). The NPMANOVA showed that there was a significant difference between the assemblages of the different sites (p=0.002), but the pair-wise comparisons between sites did not result in any significant results. The same dataset with the *Tubularia* spp. removed showed the same differentiation between the coastal and other sites. However, the distinction between the intermediate sites and offshore sites was less clear, except for the Duc de Normandie which was still clearly isolated from the other sites.

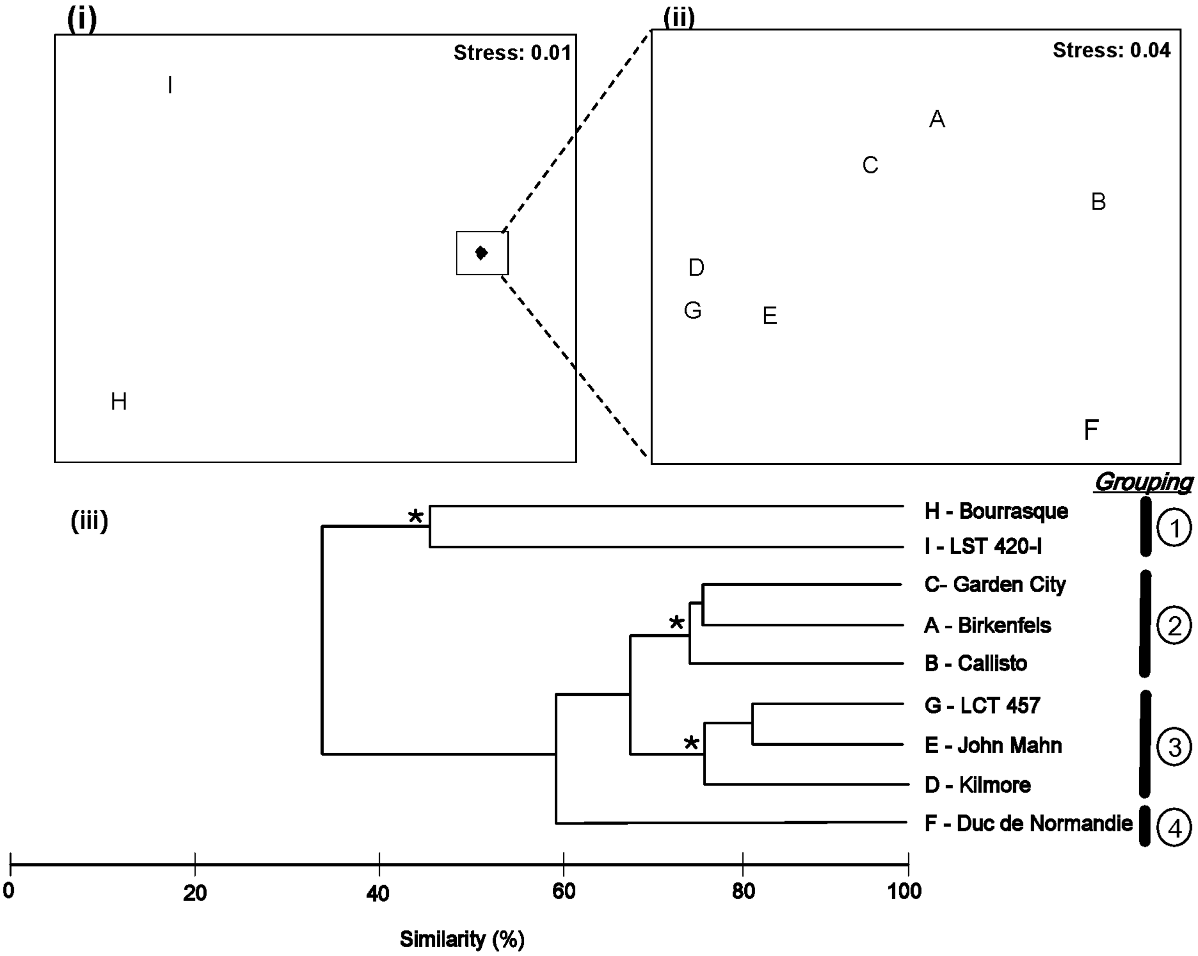


Figure 25. Multivariate analysis of similarity between sites (Bray-Curtis coefficient on square root transformed biomass data). (i) nMDS of all sites; H: Bourrasque, I: LST 420. (ii) nMDS of undiscernible sites in (A); A: Garden City, B: Birkenfels, C: Callisto, D: Kilmore, E: Duc de Normandie, F: John Mahn, G: LCT 457. (iii) Clustering of sites; * significant at p<0.05 after SIMPROF (Permutations for mean profile: 2000, Simulation permutations: 999).

Indicator species

Shipwrecks in general were represented by a large number of indicator species (Table 13). Indicator Values (IndVal) of more than 50% were found for 29 taxa. *Tubularia indivisa* was present on all samples. Many of the highest IndVal's belong to crustaceans, mainly amphipods (*Jassa herdmani*, *Phtisica marina, Stenothoe marina, Monocorophium sextonae, Pisidia longicornis, Stenothoe valida*). Offshore sites had 10 species with an IndVal higher than 50% which were all significant (two randomization tests) or partly significant (one randomization test) at $p < 0.05$. However, these species were not only present offshore. Most of them were also sampled in the intermediate sites but with a lower biomass. The difference with coastal sites was more pronounced, with many species being totally absent there. This situation was also encountered with the indicator species for intermediate sites. Thirteen species had high and most significant indicator values but were also present offshore with lower biomass. Only two species, the opistobranch *Dendronotus frondosus* and the sponge *Sycon ciliatum* had their maximum indicator value in this clustering level. Coastal sites had a distinct set of indicator species. *Tubularia larynx* did not occur in high abundances elsewhere. Four species were only present on coastal sites: *Monocorophium acherusicum, Catriona gymnota, Metridium senile* and *Obelia bidentata*. The Birkenfels and John Mahn shipwrecks had no species with IndVal above 50%. No more than two taxa were found in only one site: Gastropoda belonging to the Rissoidae in the Callisto and the opistobranch *Catriona gymnota* at the Bourrasque.

SPECIES	Ind-Val (%)	Birkenfels	Callisto	Garden city	Kilmore	John Mahn	Duc de Nomandie	LCT457	Bourrasque	LST420
All sites										
Tubularia indivisa	100	100.7/3	92.5/3	153.4/3	361.6/3	399.6/3	86.4/3	366.1/3	20.3/3	20/3
Jassa herdmani	96	65.6/3	29.5/2	86/3	123.3/3	41.2/3	26.2/3	67.8/3	1.1/3	23.6/3
Phtisica marina	96	0.1/3	0.3/3	0.6/3	1.3/3	1.7/3	0.2/3	0.6/3	0.1/2	0/3
Actiniaria	92	3.9/3	13.5/3	9.3/3	2.6/3	1.9/3	4.8/3	5.2/3	0.2/2	0.7/2
Harmothoe spp.	92	0.6/3	0.8/3	2.2/3	3.2/3	4.1/3	0.4/3	2.5/3	0/1	0.7/3
Ophiothrix fragilis	92	7.7/3	10.5/3	38.9/3	24.9/3	5/3	1.7/3	5.5/3	0/2	0.1/2
Mytilus edulis	88	1.7/3	0/2	0.4/3	1.9/3	0.1/3	0.1/3	0.4/3	0/2	0.1/2
Stenothoe marina	88	0.3/2	0.1/3	0/1	0/3	0.3/3	0.2/3	0.3/3	0.6/3	0.1/3
Monocorophium sextonae	81	0.2/3	0.1/3	0/3	0/3	0.1/3		0.5/3	0/3	0/1
Oerstedia dorsalis	81	0.3/2	0.3/2	0.2/2	1.3/3	0.5/2	0.8/3	0.4/3	0.1/2	1.2/3
Pisidia longicornis	81	4.3/2	9.3/3	9.6/3	9.5/3	7/3	1.3/3	3.5/3	0/1	0/1
Stenothoe valida	81	0.4/3	0.5/3	0.3/3	0.8/3	1.9/3	0.2/3	3.7/3	0/1	
Electra pilosa	77	0.2/3	0.4/3	0.4/3	6.4/3	0.9/3	0.3/3	0.1/2		0.1/1
Pilumnus hirtellus	77	0.3/3	1.1/2	0.7/3	1.2/3	0.7/3	0.1/3	0.5/3		0/1
Lanice conchilega	74	0/1	0/1	0.2/3	0.1/3	0.1/3	0.4/3	0.1/3		0.5/3
Lepidonotus squamatus	74	0.5/3	0/2	0.2/2	1.1/3	0.2/3	0.2/3	0.4/2		0/2
Stenothoe monoculoides	70	0/2	0.1/3	0.1/3	0.5/3	0.1/3	0/1	0.1/3		0/1
Caprella tuberculata	66	1/3	0.4/3	0.6/3	6.4/3	0/2	1/3		0/1	
Metopa alderi	66	0/2	0.5/3		0.1/2	0.6/3	0.4/3	0.1/3	0/1	0/1
Asterias rubens juv.	62		0/2		0.2/3	0.1/3	0.1/3	0.8/3		0.3/3
Phyllodoce mucosa	62		0/2	0/1	0.1/3	0.1/2	0.1/2	3.1/3	0.4/2	0/2
Amphipholis squamata	59		0/3	0.2/3	0.3/3	0/2	0/2	0/2		0/1
Pomatoceros triqueter	59	2.8/2	2.6/3	6.7/3	1.4/2	0.5/2	0.3/2	0.4/2		
Dendronotus frondosus	55			0.7/3	15.9/3	3.8/2	9.7/3	5.7/2	0/1	0.1/1
Cuthona sp.	51	0.2/3		0/1	0.1/3	0/2	0/2	0/1		0.4/2
Eulalia viridis	51	0/2	0.1/1	0.1/1	0.1/3	0/3	0/1	0.2/3		
Psammechinus miliaris	51	0/2	0.1/2	0.6/3	0.1/3	0/2		0/2		
Sabellaria spinulosa	51	0.8/2	3.6/2	0.2/2	0.2/2	0/1	0.5/3	0.1/1	0/1	
Syllis gracilis	51	0/2	0/2	0/2	0/2	0/1	0/2	0.2/3		

Offshore sites

Aequipecten opercularis	91**	0.3/3	0.3/3	0.5/3	0.1/2	0/1			0/1	
Pomatoceros triqueter	76**	2.8/2	2.6/3	6.7/3	1.4/2	0.5/2	0.3/2	0.4/2		
Actiniaria	68**	3.9/3	13.5/3	9.3/3	2.6/3	1.9/3	4.8/3	5.2/3	0.2/2	0.7/2
Ophiothrix fragilis	67**	7.7/3	10.5/3	38.9/3	24.9/3	5/3	1.7/3	5.5/3	0/2	0.1/2
Psammechinus miliaris	67 *	0/2	0.1/2	0.6/3	0.1/3	0/2		0/2		
Sabellaria spinulosa	58 *	0.8/2	3.6/2	0.2/2	0.2/2	0/1	0.5/3	0.1/1	0/1	
Heteranomia squamula	55**	0/2	0.1/2	0.3/2	0/3	0/1	0.1/2			
Musculus sp.	54**	0/2	0/1	0/2		0/1				
Nereis pelagica	53**	2.2/2	0.2/2	1.4/1			0/1	0.2/1		
Pisidia longicornis	52 *	4.3/2	9.3/3	9.6/3	9.5/3	7/3	1.3/3	3.5/3	0/1	0/1

Intermediate sites

Dendronotus frondosus	80**			0.7/3	15.9/3	3.8/2	9.7/3	5.7/2	0/1	0.1/1
Stenothoe valida	80**	0.4/3	0.5/3	0.3/3	0.8/3	1.9/3	0.2/3	3.7/3	0/1	
Electra pilosa	76**	0.2/3	0.4/3	0.4/3	6.4/3	0.9/3	0.3/3	0.1/2		0.1/1
Phtisica marina	71**	0.1/3	0.3/3	0.6/3	1.3/3	1.7/3	0.2/3	0.6/3	0.1/2	0/3
Tubularia indivisa	69**	100.7/3	92.5/3	153.4/3	361.6/3	399.6/3	86.4/3	366.1/3	20.3/3	20/3
Phyllodoce mucosa	65 *		0/2	0/1	0.1/3	0.1/2	0.1/2	3.1/3	0.4/2	0/2
Harmothoe spp.	62**	0.6/3	0.8/3	2.2/3	3.2/3	4.1/3	0.4/3	2.5/3	0/1	0.7/3
Asterias rubens juv.	62**		0/2		0.2/3	0.1/3	0.1/3	0.8/3		0.3/3
Stenothoe monoculoides	58 *	0/2	0.1/3	0.1/3	0.5/3	0.1/3	0/1	0.1/3		0/1
Sycon ciliatum	57**			0.1/1	4.5/3	0.1/1	6.3/2	0.4/1		
Lepidonotus squamatus	57 *	0.5/3	0/2	0.2/2	1.1/3	0.2/3	0.2/3	0.4/2		0/2
Syllis gracilis	57**	0/2	0/2	0/2	0/2	0/1	0/2	0.2/3		
Metopa alderi	53	0/2	0.5/3		0.1/2	0.6/3	0.4/3	0.1/3	0/1	0/1

Coastal sites

Tubularia larynx	97**	2.1/1						0.7/1	59.9/3	3/3
M. acherusicum[a]	83**								0/3	0.1/2
Stenothoe marina	50	0.3/2	0.1/3	0/1	0/3	0.3/3	0.2/3	0.3/3	0.6/3	0.1/3
Catriona gymnota	50**								1.7/3	
Metridium senile	50**								59.2/2	3.6/1
Obelia bidentata	50**								2/2	0/1

Garden City

Psammechinus miliaris	68	0/2	0.1/2	0.6/3	0.1/3	0/2		0/2		
Odontosyllis fulgurans	55**		0/1	0/3	0/1	0/1	0/1	0/1	0/1	

Birkenfels

-	-	-	-	-	-	-	-	-	-	-

Callisto

Eulalia aurea	70**	0/1	0.1/3		0/1					
Polyclinum aurantium	64 *		1/2		0/1					
Molgula cf occulta	58 *	0.1/2	0.5/2							

Kilmore

Scrupocellaria scruposa	79**		0/2		0.2/3					
Electra pilosa	72**	0.2/3	0.4/3	0.4/3	6.4/3	0.9/3	0.3/3	0.1/2		0.1/1
Caprella tuberculata	67**	1/3	0.4/3	0.6/3	6.4/3	0/2	1/3		0/1	
Amphipholis squamata	55 *		0/3	0.2/3	0.3/3	0/2	0/2	0/2		0/1
Stenothoe monoculoides	53**	0/2	0.1/3	0.1/3	0.5/3	0.1/3	0/1	0.1/3		0/1

Duc de Normandie

Myxilla rosacea	74**		0.8/1		0.6/1		4.1/3			
Halichondria cfr panicea	54 *		0.4/1				1.9/2			

John Mahn										
-	-	-	-	-	-	-	-	-	-	-
LCT 457										
Phyllodoce mucosa	81**		0/2	0/1	0.1/3	0.1/2	0.1/2	3.1/3	0.4/2	0/2
Syllis gracilis	75**	0/2	0/2	0/2	0/2	0/1	0/2	0.2/3		
Nemertinata sp.1	58 *		0/1					0.2/2		
Turbellaria	57 *			0/1				0.1/2		
Asterias rubens juv.	52**		0/2		0.2/3	0.1/3	0.1/3	0.8/3		0.3/3
Monocorophium sextonae	50**	0.2/3	0.1/3	0/3	0/3	0.1/3		0.5/3	0/3	0/1
Bourrasque										
Catriona gymnota	100**								1.7/3	
Tubularia larynx	91**	2.1/1						0.7/1	59.9/3	3/3
Balanus crenatus	66 *						0/1		0.5/2	
Obelia bidentata	65 *								2/2	0/1
Metridium senile	62 *								59.2/2	3.6/1
LST 420										
Eumida sp.	60**							0/1		0/3
M. acherusicum[a]	51								0/3	0.1/2

Table 13. Indicator species values (IndVal), mean biomass (g AFDW.m^{-2}) and presence of species at different clustering levels. Only species with IndVal > 50% are considered. The first figure is the mean biomass for the three samples of the site; if the mean biomass is lower than 0.1 g AFDW.m^{-2}, it is rounded to 0. The second figure is the number of samples where the species is present for the site under consideration. Species in bold have reached their maximum indicator value. ** Significant at $p < 0.05$ level for the two randomization tests. * Significant at $p < 0.05$ level for only one of the two randomization test.

Temporal variability

We present here the result of the time-series taken on the Kilmore shipwreck.

Diversity of epifaunal assemblages

The univariate index of diversity data are presented on figure 26. The total number of species was 104. The species richness (N_0) varied from 15 in October to 42 in August with a mean value of 33 species per sample. All the other species richness values lay between 30 and 40 species with the exception of the samples from March 2005 (28 sp).

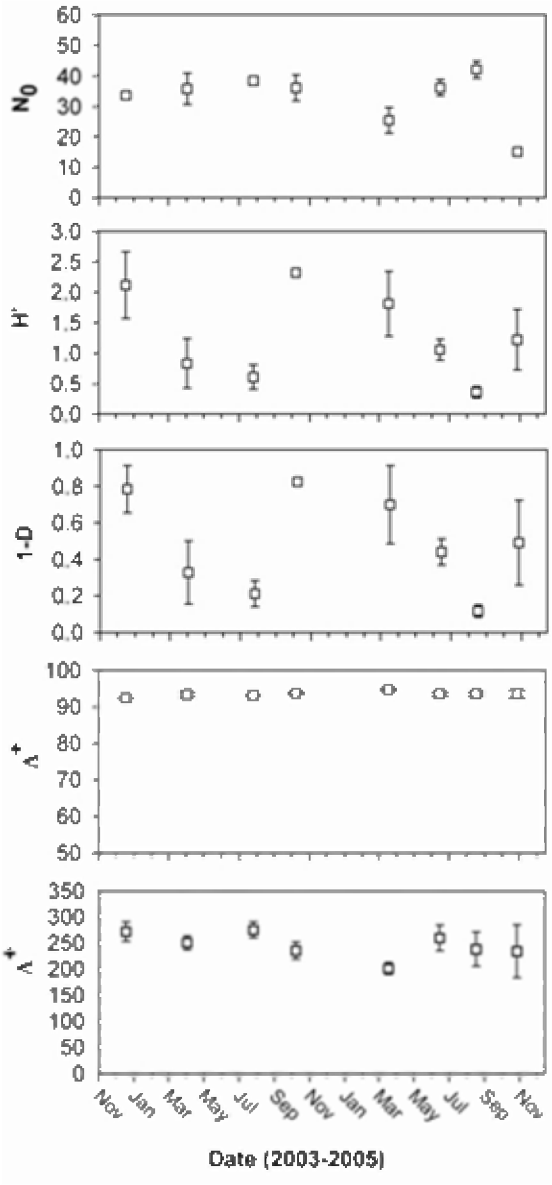


Figure 26 Temporal variation of diversity index on the Kilmore shipwreck. Values are means ±s.d. N_0 is the species richness, H' is the Shannon-wiener index (natural log), 1-D is the Simpson index, Δ^+ is the taxonomic distinctiveness, Λ^+ is the variation in taxonomic distinctiveness.

The results of the Kruskal-Wallis ANOVA was significant at $p<0.03$, indicating that species richness was different from date to date. The Shannon-Wienen (H', $\log_e$) and Simpson (1-D) index displayed a very similar pattern. The samples from the fall and winter periods shared high diversity index values while spring and summer samples were strongly dominated by a few species. The Kruskal-Wallis ANOVA is significant at $p<0.03$ and $p<0.04$ for H' and 1-D, respectively. The taxonomic distinctness (Δ^+) values had no distinct pattern linked to time of the year. The average taxonomic distance between two species taken at random did not change with time. The variation in taxonomic distinctness (Λ^+) was also rather constant. Only two values, one at the end of 2004 and the other at the beginning of 2005 were lower, indicating a more homogeneous repartition of the species in the taxonomy of these samples.

Density and biomass

The total density of the macrobenthos displayed a clear temporal variation with larger values during the spring and summer period (Figure 27). It ranged from 6,500 ind.m^{-2} in October 2004 to 445,800 ind.m^{-2} in July 2004. A major part of these individuals were due to the amphipod *Jassa herdmani* (Figure 20). Its density ranged from 1,000 ind.m^{-2} in October 2004 to 398,500 ind.m^{-2} in July 2004 and closely followed the pattern of the total density. The abundance of Crustacea (*J. herdmani* omitted) and Echinodermata had a peak of abundance during the spring and summer months (33,000 ind.m^{-2} and 12,100 ind.m^{-2} in June 2006 and July 2004, respectively; Figure 27). For the Crustacea, the decapod *Pisidia longicornis* and the caprellids *Phtisica marina* and C*aprella tuberculata* were the most contributing species to the observed abundances (Figure 27).

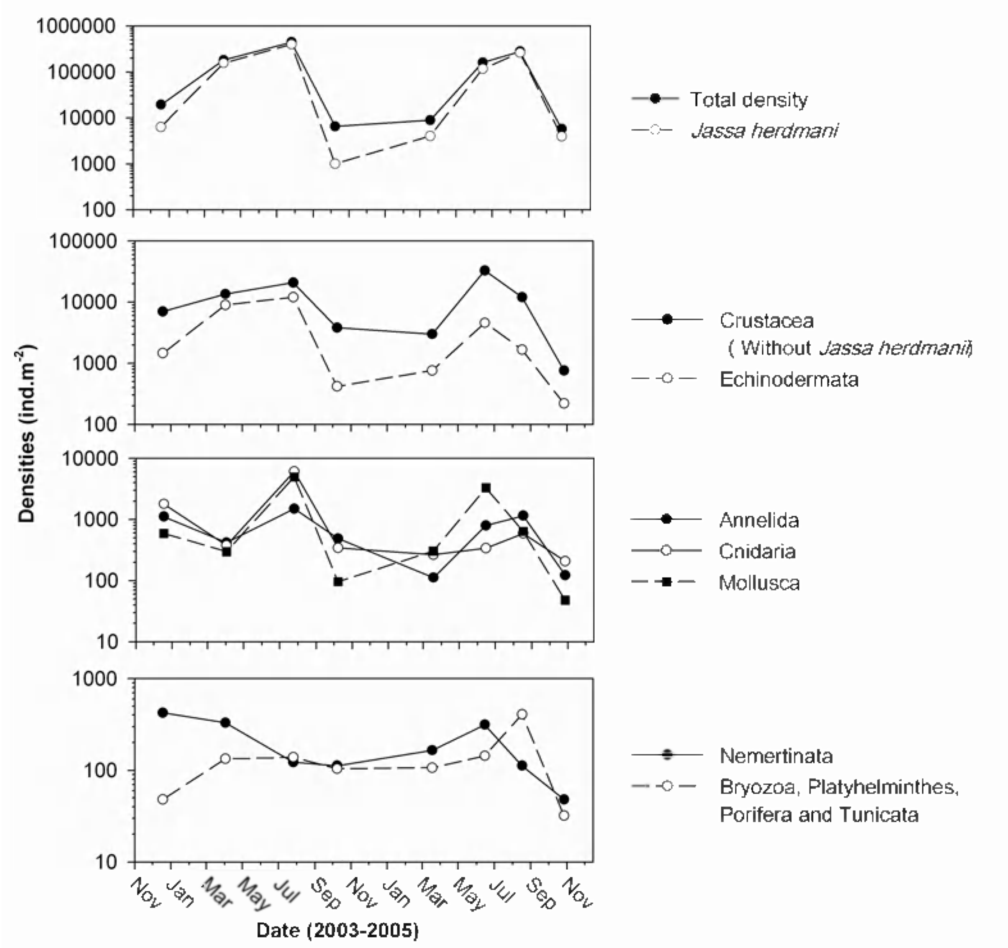


Figure 27. Temporal variation of densities on the Kilmore shipwreck. Y axes are presented on a log scale.

Stenothoidae were also abundant. *Ophiothrix fragilis* dominated the Echinodermata (Figure 27). Annelida, Cnidaria and Mollusca had a very close pattern of temporal abundances. They were all more abundant in spring and summer with maximal abundances of 1,500 ind.m^{-2} for Annelida, 6,100 ind.m^{-2} for Cnidaria and 5,000 ind.m^{-2} for Mollusca. However, some of the cnidarians species were not readily countable and were not adequately represented by abundance data. Groups with low abundance like Nemertinata, Porifera, Platyhelminthes, Bryozoa and Tunicata did not show any clear temporal pattern.

The total biomass varied from 9 g.m^{-2} in October 2004 to 1,106 g.m^{-2} in July 2004 (Figure 28; all biomass values are expressed as ash-free dry weights). The variation in total biomass was under the strong dependence of the biomass of *Tubularia indivisa* which constituted between 59 and 82% of the total biomass (Figure 28). Its development was already important at the end of winter (60-324 g.m^{-2}) and increasing until the first part of the summer period

(362-912 g.m^{-2}). Afterwards, its biomass was decreasing with its minimal development being around October (5-14 g.m^{-2}). The biomass of the most abundant species, *J. herdmani*, displayed the same pattern with biomass ranging from 0.3 to 123.3 g.m^{-2} (Figure 28). The height most abundant species have their biomass values presented on figure 28. For June 2005, with *T. indivisa* and *J. herdmani*, they accounted for 93% of the biomass measured from each individual on the samples. Except the amphipod *Monocorophium sextonae* and the tunicate *Diplosoma* sp., they all had a peak of biomass at the end of spring. The last two species were more represented at the end of winter. Generally, the biomass values on 2004 were higher than on 2005. In July 2004, the biomass of *T. indivisa* was 912 g.m^{-2} while they were 362 and 129 g.m^{-2} in June and August 2005, respectively.

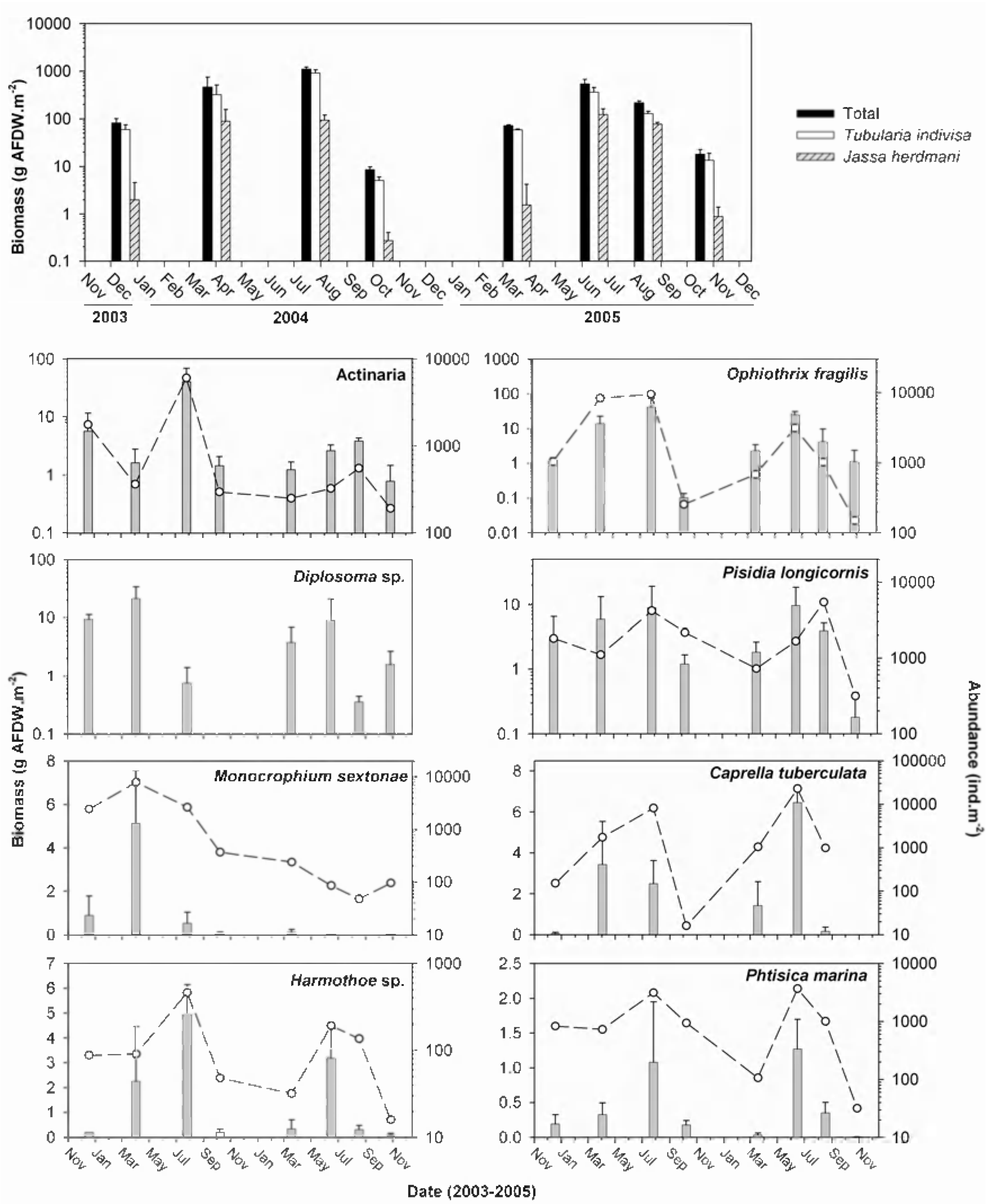


Figure 28. Temporal variation of biomass (mean ash-free dry weights, ±s.d.) and abundance of dominant species on the Kilmore shipwrecks. Abundance for *Diplosoma* sp. is not presented because this species is not countable. For readability, Y axes of Actinaria, *Ophiothrix fragilis*, *Diplosoma* sp. and *Pisidia longicornis* are presented on a logarithmic scale.

There was a correlation between the biomass of *T. indivisa* and the abundance of *J. herdmani* (Figure 29; Spearman R^2=0.562, p<0.008), and the number of species in the samples (R^2=0.895, p<0.001). *T. indivisa* biomass was also negatively correlated with the Shannon-Wiener index (R=-0.677, p<0.001) and the Simpson index (R=-0.650, p<0.002) but was not correlated with the taxonomic distinctiveness and variation in taxonomic distinctiveness.

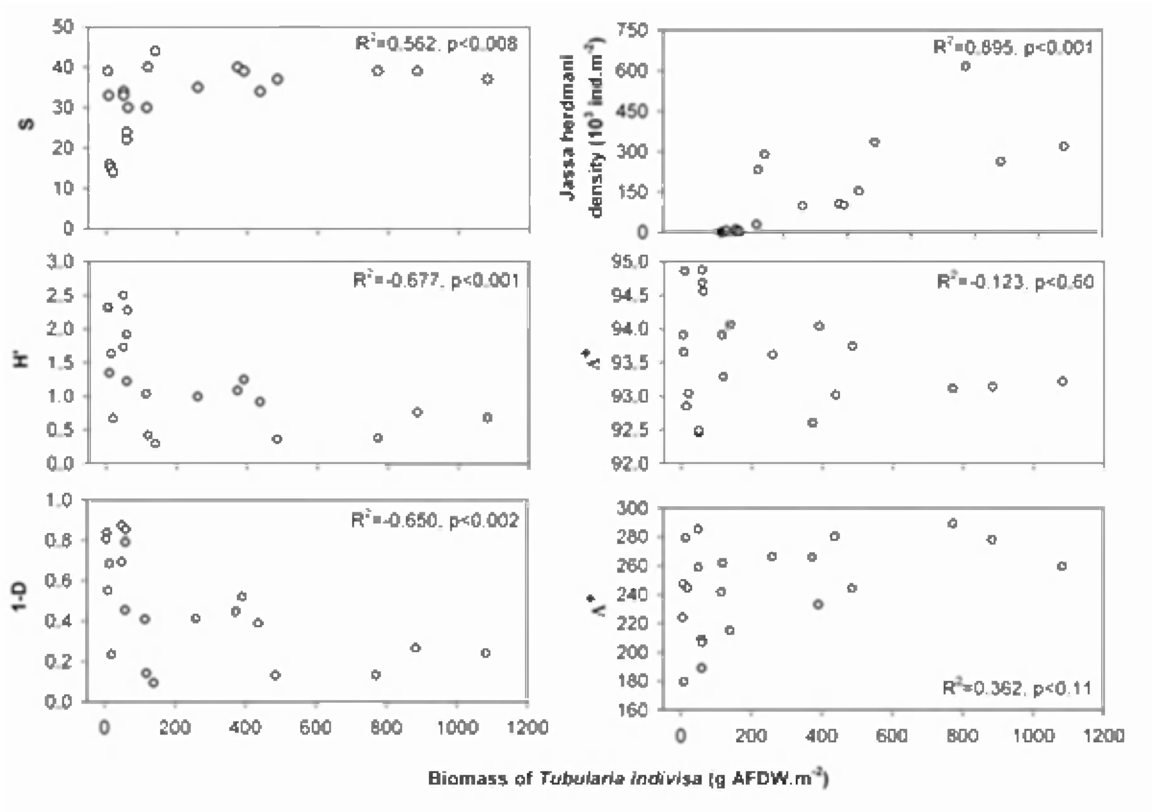


Figure 29. Spearman rank order correlation between standing biomass of *Tubularia indivisa* and univariate measures of diversity. N_0 is the species richness, H' is the Shannon-wiener index (natural log), 1-D is the Simpson index, Δ^+ is the taxonomic distinctiveness, Λ^+ is the variation in taxonomic distinctiveness.

The number of species which were associated with *T. indivisa* (meaning living attached on or invariably found on *T. indivisa*) was generally superior to 55% of the species richness of the samples (Figure 30). Only the sample of October 2004 had 46% of its species depending on *T. indivisa*. This set of species accounted for 86% (December 2003) or more of the total density of individuals in the samples (Figure 30). However, there was no systematic trend in the association (both in species number and density) with the period of the year.

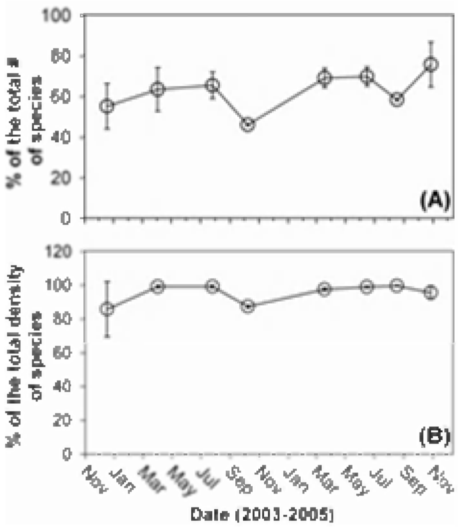


Figure 30. Temporal variation of the % of total number (A) and density (B) of species which are associated with *Tubularia indivisa*.

Multivariate pattern

The non-metric multidimensional scaling ordination plot (abundance data) of the assemblages from each date showed a good consistency for the samples taken on the same dates (Figure 31). Only the variance for the samples from December 2005 was larger. The samples from spring and summer grouped together, especially with the √√ transformation on abundance data (Figure 31,A). When ordinating the samples on the presence/absence of species, they still isolated but less sharply. With presence/absence data, the weights of the abundant species found during spring and summer was not marked anymore and the similarity between samples tended to increase. The samples from December 2003 and October 2004 and 2005 had a different assemblage pattern from each other and from the other samples (Figure 31,B).

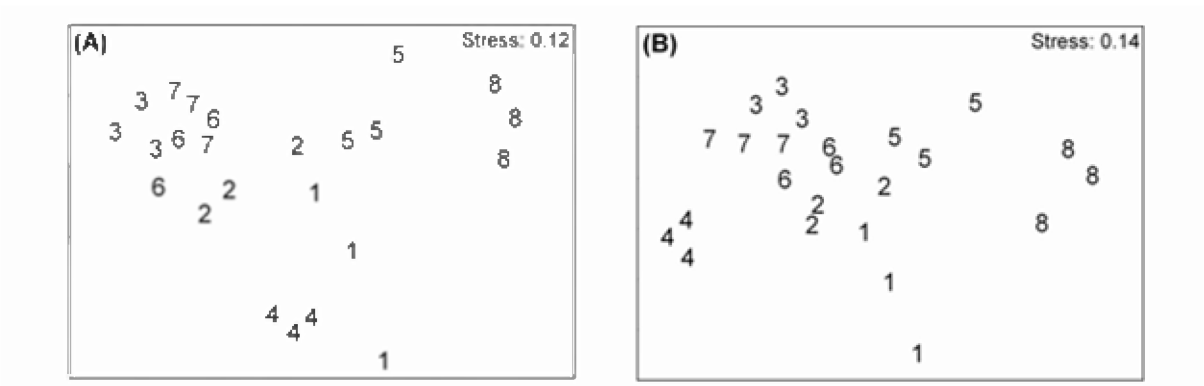


Figure 31. non-Metric Multidimensional Scaling based on Bray-Curtis similarity from √√ abundance data (A) and presence/absence data (B). 1: December 2003, 2: April 2004, 3: July 2004, 4: October 2004, 5: March 2005, 6: June 2005, 7: August 2005, 8: October 2005.

The ordination plot for biomass data isolated the spring and summer samples from the autumn and winter ones (Figure 32). However, the distance between each date was superior to the abundance pattern, individualizing the dates more clearly.

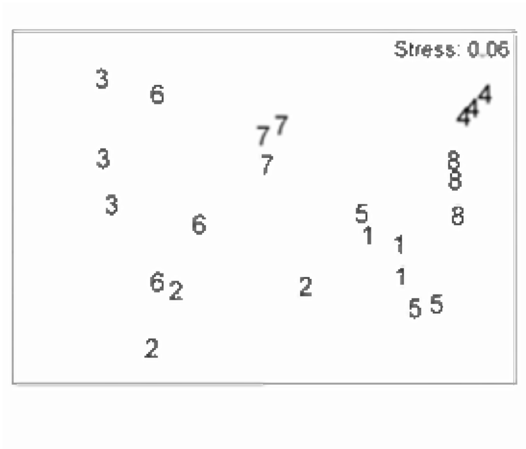


Figure 32. non-Metric Multidimensional Scaling based on Euclidian distances from √√ biomass data. 1: December 2003, 2: April 2004, 3: July 2004, 4: October 2004, 5: March 2005, 6: June 2005, 7: August 2005, 8: October 2005.

Seasonal characteristic species

The number of species which were indicator of the Kilmore shipwreck was relatively high (16 species with IndVal>75; table 14). The best represented group was the crustaceans with decapods and amphipods. *Mytilus edulis* was invariably found as juveniles (<1 cm) while all the other species had adults in their representatives. The indicator species by season are presented on table 15. Except for *Liocarcinus* sp. in winter, the IndVal were low and there was a low number of species which were significantly indicator of a season with certitude. In winter, several polychaete and crustacean species had an IndVal around 50. The cnidarian *Alcyonium digitatum* was the second indicator species. This species was only found as juveniles composed of a few polyps which were not found afterwards. *Monocorophium sextonae*, although not significantly, was again more characteristic of the winter period. In spring, two sponge species (*Esperiopsis fucorum* and *Halichondria* cf *panicea*) were ubiquitous together with the pioneer polychaete *Pomatoceros triqueter* and juveniles of *Aequipecten opercularis*. The only significant species was the bryozoan *Scrupocellaria scruposa* which was developing on the perisarc of *T. indivisa*. During summer, four species of polychaetes (*Eusyllis blomstrandi*, *Phyllodoce mucosa*, *Lanice conchilega* and *Harmothoe* sp.) were indicator of the assemblages. Not indicator but potentially important because of their predatory behaviour on *T. indivisa*, the nudibranch *Dendronotus frondosus*, the syllid *Procerastea halleziana* and the pycnogonid *Achelia* sp. were abundant in summer. The amphipod *Stenothoe monoculoides* together with *M. edulis* and *J. herdmani* were also characteristics of the assemblage. In fall, cnidarians (*Obelia* sp. and *clytia hemisphaerica*) and the polychaete *Eumida* sp. were indicator species.

Species		IndVal	Species		IndVal
1. Actiniaria	CNI	100	9. *Mytilus edulis*	MOL	95.2
2. *Jassa herdmani*	CRU	100	10. *Pilumnus hirtellus*	CRU	95.2
3. *Oerstedia dorsalis*	NEM	100	11. *Phtisica marina*	CRU	90.5
4. *Ophiothrix fragilis*	ECH	100	12. *Caprella tuberculata*	CRU	85.7
5. *Pisidia longicornis*	CRU	100	13. *Diplosoma* sp.	TUN	85.7
6. *Tubularia indivisa*	CNI	100	14. *Harmothoe* sp.	POL	85.7
7. *Amphipholis squamata*	ECH	95.2	15. *Lepidonotus squamatus*	POL	81.0
8. *Monocorophium sextonae*	CRU	95.2	16. *Stenothoe monoculoides*	CRU	81.0

Table 14. Indicator species of the temporal series from the Kilmore shipwreck. The indicator values (IndVal) were calculated from √√ transformed abundance data. Only the species with indicator values above 75 are presented. CNI: Cnidaria, CRU: Crustacea, ECH: Echinodermata, MOL: Mollusca, POL: Polychaeta, TUN: Tunicata.

Species		IndVal	Sign.
WINTER			
Liocarcinus sp.	CRU	**100.0**	**
Alcyonium digitatum	CNI	**68.6**	**
Polyclinum aurantium	TUN	**56.9**	*
Macropodia parva	CRU	**56.1**	*
Rissoidae	MOL	**56.0**	**
Sabellaria spinulosa	POL	**53.8**	*
Cumacea sp.	CRU	**50.0**	*
Epitonium clathratulum	MOL	**50.0**	*
Eunicidae	POL	**50.0**	*
Euspira pulchella	MOL	**50.0**	*
Phyllodoce mucosa	POL	**50.0**	*
Polycirrus sp.	POL	**50.0**	*
Sthenelais boa	POL	**50.0**	*
Thelepus setosus	POL	**50.0**	*
Thoralus cranchii	CRU	**50.0**	*
Tubulanus sp.	NEM	**50.0**	*
Stenothoe marina	CRU	43.5	NS
Bicellariella ciliata	BRY	**37.5**	NS
Nassarius incrassatus	MOL	**37.0**	NS
Monocorophium sextonae	CRU	32.8	NS
Oerstedia dorsalis	NEM	31.4	**
SPRING			
Esperiopsis fucorum	POR	43.2	NS
Scrupocellaria scruposa	BRY	**43.1**	*
Halichondria cf *panicea*	POR	39.0	NS
Pomatoceros triqueter	POL	38.5	NS
Aequipecten opercularis	MOL	35.3	NS
Jassa herdmani	CRU	42.4	**
SUMMER			
Eusyllis blomstrandi	POL	**55.6**	*
Phyllodoce mucosa	POL	53.9	**
Lanice conchilega	POL	**51.9**	**
Stenothoe monoculoides	CRU	50.4	**
Psammechinus miliaris	ECH	46.5	NS
Eulalia viridis	POL	45.2	NS
Procerastea halleziana	POL	**44.4**	NS
Asterias rubens	ECH	**44.4**	NS
Mytilus edulis	MOL	43.0	**
Jassa herdmani	CRU	42.4	**
Caprella tuberculata	CRU	41.4	NS
Sycon ciliatum	POR	38.3	NS
Harmothoe sp.	POL	36.2	*
FALL			
Clytia hemisphaerica	CNI	**50.0**	**
Eumida sp.	POL	**50.0**	**
Obelia sp.	CNI	**50.0**	**

Table 15. Indicator species by season on the Kilmore shipwreck. The indicator values (IndVal) were calculated from √√ transformed abundance data. Maximal IndVal were bolded. Only the species with IndVal above the last significant IndVal were included. ** Significant at $p < 0.05$ level for the two randomization tests. * Significant at $p < 0.05$ level for only one of the two randomization test. NS: not significant.

BEWREMABI website

Since communication is essential, a website was elaborated to promote the exchange of information at scientific and public levels. The project website (http://www.vliz.be/projects /BEWREMABI) is hosted and maintained by VLIZ. The site holds some general information about the project and its objectives, background and activities (Figure 33). Furthermore, some useful information, like an overview of all cruises and a preliminary list of encountered species, can be downloaded from the website. There is also a literature list available of co-authored papers resulting from the project. In the media gallery some exclusive photo material and movies on sampling campaigns and encountered species are made available to the public (Figure 34).

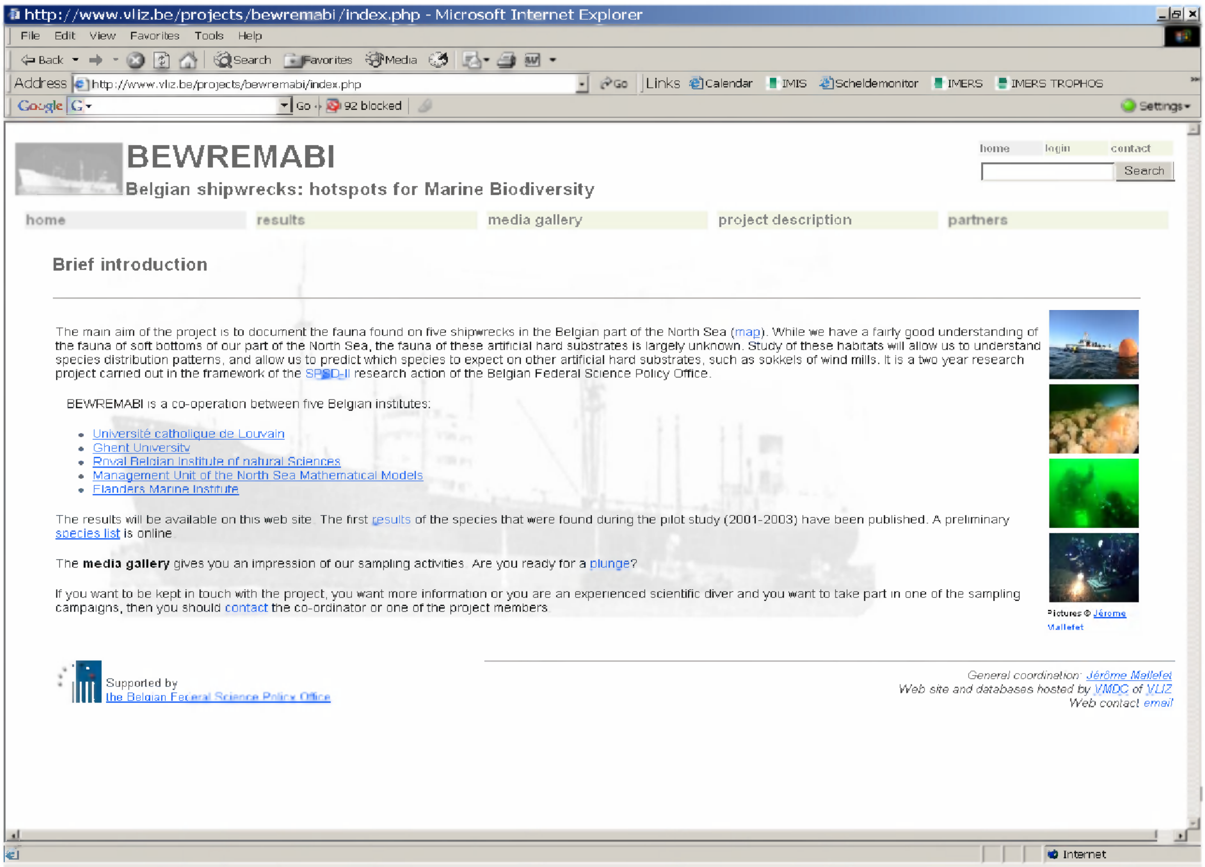


Figure 33: BEWREMABI website

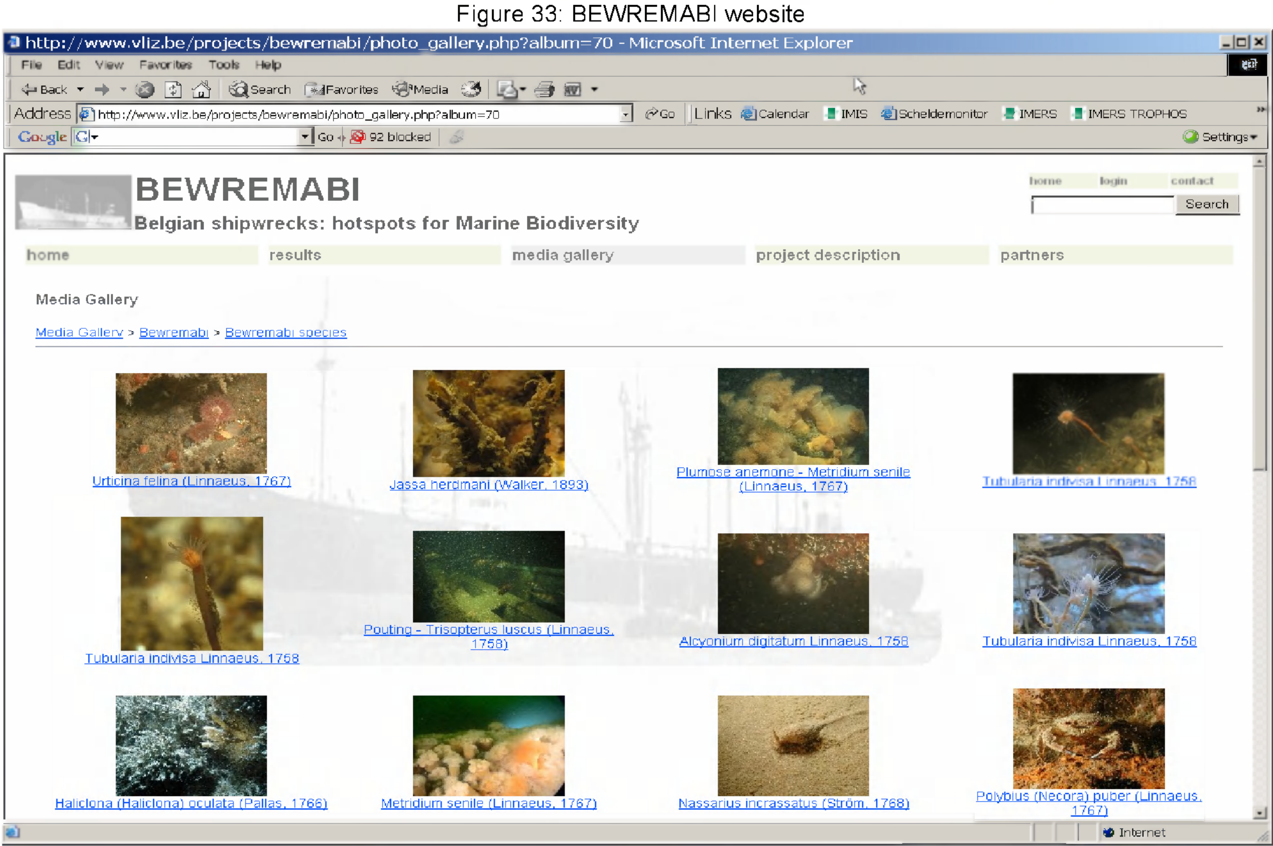


Figure 34: media gallery on BEWREMABI website

Data management in BEWREMABI:

Increasing the data-availability and providing more elaborate possibilities for exchange of data towards other projects (and towards the scientific community in general) was one of the main objectives within the BEWREMABI data management. This was realized through the development of an integrated project database. The BEWREMABI integrated project database is the database that holds the actual data that was gathered during the project (Figure 35). The set-up of the database is suitable for storing both physical and non-physical data. All data is linked to information on its origin. In the database the measured values or *readings* are linked to information on their corresponding *trip* or cruise, *visit* to station, sampling or measurement *event*, *sample, biotic record, methodology, data-originators,* etc. As far as possible all data is stored in an integrated way, this means that data that was collected together remains linked and can be retrieved as such. For example, when species presence (identification in lab, only available in delayed modus) was determined at a certain station, the corresponding CTD data (electronic, data available immediately) for this station at that time will be linked to these species presence data. All data was linked to standard vocabularies like the European Register of Marine Species (ERMS) taxonomic reference list and the European marine gazetteer. This increases the possibilities for (international) exchange of data. All data was exported from the project database and transferred in 'common layout' format to MUMM for uptake into the IDOD database.

2006_BEWREMABI_check_Administration : Select Query

StartSampleDateTime	PlaceName	Latitude	Longitude	TaxonName	Reading	UNIT
03/06/2005	LST 420	51,25767	2,679267	Stenothoe marina (Bate, 1856)	0,057	g
27/06/2005	Garden city	51,48566	2,30535	Psammechinus miliaris (Gmelin, 1778)	0,057	g
29/06/2005	John Mahn	51,48228	2,688983	Stenothoe marina (Bate, 1856)	0,057	g
29/06/2005	LCTR 457	51,41118	2,7285	Pilumnus hirtellus (Linnaeus, 1761)	0,057	g
27/06/2005	Garden city	51,48566	2,30535	Aequipecten opercularis (Linnaeus, 1758)	0,058	g
29/06/2005	LCTR 457	51,41118	2,7285	Nemertinea spp.	0,058	g
15/06/2006	Kilmore	51,3873	2,4879	Psammechinus miliaris (Gmelin, 1778)	0,058	g
04/05/2005	Bourrasque	51,2494	2,5504	Stenothoe marina (Bate, 1856)	0,059	g
17/06/2005	Calysto	51,7	2,6247	Polyclinum aurantium Milne-Edwards, 1841	0,059	g
03/06/2005	Duc de Norman	51,42528	2,60565	Pilumnus hirtellus (Linnaeus, 1761)	0,06	g
03/06/2005	Duc de Norman	51,42528	2,60565	Asterias rubens	0,062	g
17/06/2005	Calysto	51,7	2,6247	Stenothoe valida	0,062	g
29/06/2005	LCTR 457	51,41118	2,7285	Sabellaria spinulosa Leuckart, 1849	0,062	g
15/06/2006	Kilmore	51,3873	2,4879	Cuthona nana (Alder & Hancock, 1842)	0,063	g
03/06/2005	Duc de Norman	51,42528	2,60565	Caprella tuberculata Guérin, 1836	0,064	g
29/06/2005	John Mahn	51,48228	2,688983	Amphipholis squamata (Delle Chiaje, 1829)	0,064	g
29/06/2005	John Mahn	51,48228	2,688983	Asterias rubens	0,064	g
15/06/2006	Kilmore	51,3873	2,4879	Asterias rubens	0,066	g
29/06/2005	John Mahn	51,48228	2,688983	Metopa alderi (Bate, 1857)	0,067	g
29/06/2005	John Mahn	51,48228	2,688983	Monocorophium sextonae Crawford, 1937	0,067	g
17/06/2005	Calysto	51,7	2,6247	Caprella tuberculata Guérin, 1836	0,068	g
29/06/2005	John Mahn	51,48228	2,688983	Lanice conchilega (Pallas, 1766)	0,068	g
17/06/2005	Calysto	51,7	2,6247	Nassarius incrassatus (Ström, 1768)	0,069	g
15/06/2006	Kilmore	51,3873	2,4879	Heteranomia squamula (Linnaeus, 1758)	0,069	g
29/06/2005	LCTR 457	51,41118	2,7285	Metopa alderi (Bate, 1857)	0,07	g
17/06/2005	Calysto	51,7	2,6247	Stenothoe marina (Bate, 1856)	0,071	g
15/06/2006	Kilmore	51,3873	2,4879	Pilumnus hirtellus (Linnaeus, 1761)	0,071	g
18/05/2005	Birkenfels	51,64981	2,5378	Heteranomia squamula (Linnaeus, 1758)	0,072	g

Record: 1

Figure 35: biotic records in BEWREMABI project database

Meanwhile, the BEWREMABI database contains a substantial amount of data. All together - this means, including the data resulting from the BCS Wreck Fauna pilot study "2001-2003" - the database stores over 4.800 measured values or so called 'readings'. Most of these readings are linked to biotic records: abundances (qualitative or quantitative) and wet weight biomass. The database contains data on a little bit over 300 taxa encountered on or surrounding the shipwrecks. Together with these biological readings some environmental data is stored either as individual readings, either as link to the corresponding CTD files.

The concept of the database is as such that, the BEWREMABI database is in fact a subset of a larger repository, the IMERS database (= Integrated Marine Environmental readings and samples). This repository will be further developed, managed, back-upped, quality controlled, updated and completed in the framework of future projects. In this way, data availability and possibilities for exchange of the BEWREMABI data for the future are guaranteed, even after the ending of the project.

Discussion

The presence of artificial reefs on the Belgian Continental Shelf

Artificial reefs represent a popular and accessible technology for modifying aquatic ecosystems. Their deployment, mainly in coastal waters has increased significantly over the past two decades (Seaman, 2000). Originally, artificial reefs were built for the interests of a variety of commercial, recreational, conservation and management sectors. However, every artificial reef is not supported by an original goal, either because their planning is poorly designed or more simply because a wealth of hard structures are spread over the sea bottom for a diversified set of reasons implying the presence of man at sea. Shipwrecks on the Belgian Continental Shelf (BCS) can be considered as such unplanned artificial reefs. They were not purposely sunk, but still, they inevitably act as artificial reefs. Another example for the Belgian waters is the future implantation of windmill fields which will add a significant new amount of hard substrates. In a context of growing manipulation of our coastal environment, the subtidal positioning and large repartition of shipwrecks allow them to be interesting models for the evaluation of artificial hard substrate impacts at sea.

Occurrence and repartition of artificial hard substrate

Up to now, 231 obstruction points, most of them being shipwrecks, are officially recognised by the Administration for Navigation and Coast of Belgium. This figure represents a significant number of artificial reefs on the BCS. 19% of the shipwrecks lay under navigation routes and 23% at less than two nautical miles from harbours. 83% of the shipwrecks are at less than 30 km from the coast. It means that generally, a wreck can be found at each node of a grid of 3.87 km side, but on the coastal zone, this grid would have a size of 3.01 km and offshore a size of 6.64 km. They totalise an area lying between 0.85 km^2 and 1.49 km^2. These estimations represent 0.025% and 0.043% of the surface of the BCS which is relatively low. However, if taking into account the biomass from shipwrecks epifauna compared to the biomass on soft sediment, this percentage may increase to 4% for the BCS (see below). The frequency and repartition of shipwrecks for the neighbouring countries are in the same range. It points out to a discrete but extended network of artificial hard substrates created by shipwrecks.

General condition of the shipwrecks

The older site made of steel on the BCS is the Kilmore which sunk in 1906. World War I and II are responsible for a large part of the ship wreckages (26%). Other sinkings were caused by collisions and storm events. Divers observed that coastal shipwrecks which are always in shallow waters (<20 m) are generally in poor conditions, often buried in sand and largely broken into small pieces, while further offshore, they are still well preserved. For example, the Kilmore is underwater for 100 years and most of its structures are still clearly identifiable. On relatively protected conditions, the life span of shipwrecks is potentially long and further enhanced by the presence of fouling organisms which prevent the direct exposure of steel to sea water (Gabriele et al., 1999; Sun et al., 2003). This is particularly true for organisms strongly attached to the surface by calcification such as barnacles or serpulid polychaetes(Ma, 1989). These organisms were abundant on the studied shipwrecks. The evolution of their structural complexity with time is susceptible to affect their habitat value especially for fishery resources (Steimle & Zetlin, 2000).
Although outside the scope of this study, it should be noted that the value of shipwrecks does not only rely on their biological colonization but also on their archaeological heritage. We are at the premise of this work and a lot of information has still to be collected on our maritime history (Pieters, 2006).

Abiotic environment

The maximum depth of the BCS is about 40 m and tides highly influence the distribution of sediments and their benthic communities (Larsonneur et al., 1982). Mean spring tide amplitudes are around 4 m. East of the Dover Strait, current velocities decrease as a result of the increasing opening between continental Europe and UK after the Dover Strait, allowing for the sedimentation of finer particles. Soft sediments dominate the seabed of the Belgian part of the North Sea (BCS). As a general rule, offshore shipwrecks are located in deeper waters while coastal sites are shallower.

On the basis of temperature, salinity, turbidity and currents information, we could discern three zones. (1) A coastal zone with periodic salinity decreases (from 35.1 down to 28.1), large seasonal temperature fluctuation (0.4-21.9°C), high total suspended matter load (mean monthly value up to 20.9 $mg.l^{-1}$) and reduced current velocity, (2) An offshore zone with more stable temperature (4.7-20.3°C) and salinity (33.8-35.3) environment, less turbid waters (up to 6.2 $mg.l^{-1}$) and high current speed, (3) An intermediate zone with intermediate results for the abiotic parameters and fast current velocities. These differences are the result of stronger influence offshore of the Channel waters from the Atlantic and influence of freshwater input from the Scheldt – Rhine estuary inshore. These three zone were already defined by Govaere et al.,(1980), based on the macrobenthos of soft sediments and by M'harzi et al.,(1998) based on phyto- and zooplankton communities.

The monthly variation of abiotic parameters for an intermediate site (Kilmore) showed the following conclusions: (1) the water temperature varied between 4.2°C in March and 20.3°C in August, (2) salinity showed few variations around 33.9, (3) bottom tidal currents followed a semi-diurnal cycle and were preferentially NE oriented with 84% of them in the range 0.25-0.75 $m.s^{-1}$, (4) mean value for total suspended matter was 6.2 $mg.l^{-1}$ with large variations at a monthly scale.

Information on the abiotic parameters on different part of one shipwreck is missing. The orientation of shipwrecks with the prevailing water direction must have an influence on the distribution of species on the shipwrecks as it has already been shown on tropical waters (Baynes & Szmant, 1989). Some part on the shipwrecks may be more protected/exposed than others. This differential exposition could result in discrepancies in the epifauna species that will preferentially develop. Further research on the local variation (at the scale of one shipwreck) of abiotic parameters would be needed to solve this question.

Macro-epifauna on shipwrecks

The fauna of shipwrecks in a context of soft-sedimented continental shelf

The current pooled species richness for Belgian shipwrecks is 224 sp. Among these taxa, 22 were observed *in situ* or after examination of digital picture while the other were directly collected. All the collected material is housed in the collections of the Royal Belgian Institute of natural Sciences (IG number: 29462). Forty six of them are new for the Belgian fauna (Zintzen & Massin, submitted). The sessile and vagile species represented 23% and 77% of the species, respectively. In this order, the Annelida, Arthropoda, Mollusca, Cnidaria and Bryozoa were the most species rich phyla

It must be pointed out that macroalgae were not observed on the shipwrecks during the BEWREMABI project. This absence of Chlorophyta, Phaeophyta and Rhodophyta is puzzling because they are known to occur on the BCS mainly on artificial hard bottoms (groins, buoys, jetties, pillars,…), located in the intertidal zone (Daro 1969, 1970, Volckaert *et al.,*2004). The absence of Chlorophyta and Phaeophyta might be linked to the low light intensity around the shipwrecks due to either the high suspended matter in the water column surrounding coastal shipwrecks or water depth for wrecks located offshore. Moreover the presence of grazers (*Psammechinus miliaris*) sometimes in great number, prevent the development of these algae. Although it is known that some Rhodophyta are able to grow in environment with limited light intensity, it is plausible that their very slow growing rate might be limited by the numerous and very fast growing fauna as Cnidaria (*Tubularia ssp, Metridium senile*) or sessile Crustacea (*Jassa herdmanni*). Finally one cannot exclude the abrasive effect of sediments, moved by the tidal currents, around the base of the shipwrecks. Shipwrecks from Belgian waters are patches of hard substrate in sea beds dominated by soft sediments. Species, trophic and biomass analysis of this study showed that soft sediments and artificial hard substrates (shipwrecks) are distinct habitats. The presence of these hard substrate patches in a soft sediment dominated sea bed increased the structural (new species) as well as functional diversity (different abundance and biomass patterns, different trophic structure) of the Belgian waters.

Species pattern

The results indicate that few species are shared by these two habitats (9.6%) and that their faunal assemblages are distinct. There is a shift from a habitat dominated by bivalves and polychaetes on soft sediments to shipwrecks dominated by crustaceans, polychaetes and cnidarians. Diversity indices show that shipwrecks are more species rich and that their taxonomic diversity is also higher than on soft sediments. Shipwrecks are strongly dominated by suspension feeders and have consequently a distinct and less diversified trophic structure than what is found on the surrounding sediments.

The comparison with natural hard substrate communities from Belgian water is still limited because little data are available up to now. From a first analysis, we note that many species are shared by both habitats, but that contrary to shipwrecks, natural assemblages were not dominated by a single species (Houziaux, SPF research contract EV/36/45A).

A large area where natural hard substrate occurs exists around the Dover Strait where the distance between France and UK is the smallest and tidal currents the highest. The fauna of the pebble community from the Dover Strait has been better documented and it appears that, the dominating sessile species are not the same (Foveau, 2005; Alizier, 2005). In the pebbles of the Dover Strait, the sessile fauna is mostly dominated by bryozoan species and the octocoralian *Alcyonium digitatum*, while the largest fraction of the sessile epifauna of shipwrecks belonged to the hydrozoans and actinarians (*Tubularia* spp. and *Metridium senile*).

Different hypotheses can be raised to explain these differences. First, since shipwrecks offer a structure which protrudes from several meters above the seabed, they could well provide a habitat more protected to sand abrasion than pebbles. The strong hydrodynamic in the area associated with the presence of sand can have an abrasive effect on species. This is highlighted by the presence of species adapted to sand abrasion like the tube annelid *Sabellaria spinulosa* in the Dover Strait (Davoult & Clabaut, 1988). However, *S. spinulosa* was also identified on shipwrecks, showing that shipwrecks are not entirely protected from sand abrasion. Secondly, the stability of both substrates is different. Particularly strong currents or storm events might have a more profound effect on pebbles than on the rigid and large structure of shipwrecks (Posey et al., 1996). Under the effect of these events, pebbles can be moved and the epifauna damaged or covered by sand transport. On shipwrecks, important storm events can lead to the collapsing of a part of the superstructure but frequent small scale perturbation events are unlikely to occur. Thirdly, passive suspension feeding seems to be the privileged mode of nutrition on both habitats. The rate of particles filtered by an organism is a function of particle density and current velocity. This last parameter could be enhanced on shipwrecks because current speed is higher at increasing distance from the bottom and when it encounters an obstacle. Finally, human activities like fisheries are more intense on natural grounds like pebbles than on shipwrecks and might also lead to more frequent perturbations on pebbles. This can have strong effects on the development of epibenthic species (Engel & Kvitek, 1998; Fraschetti et al., 2001). To test this last hypothesis, the present assemblages of shipwrecks should be compared with a reference collection of natural hard substrate communities before they suffer from high fishery pressure. The collection of Gilson held at the Royal Belgian Institute of natural Sciences is currently the best available baseline resource to produce such an analysis. Gilson thoroughly sampled the BCS in the beginning of the XXth century, including gravely areas. Unfortunately he never published his results however, recently the collection were revisited by a Houziaux under a Belspo funding . When the results of this project will be published, a comparison of these data with Bewremabi data will be particularly interesting.

Nutrition and biomass

There was a strong dominance of suspension feeders on shipwrecks compared to the feeding habits in the surrounding soft sediment. In this respect, shipwreck communities have a clear affinity with the 'pebbles with epifauna' community described on the Dover Strait (Prygiel et al., 1988; Davoult, 1990; Migne & Davoult, 1997; Foveau, 2005; Alizier, 2005). Flow velocity has a marked effect on structuring benthic community. Flach et al.,(1998) noted that an increased density of suspension feeders was observed where flow velocity increased. Sessile suspension feeders rely on the movement of water to fulfil their food requirement. The potential food available to the taxa is a function of particle concentration and rate at which particle can be delivered. When suspension feeders are active on or near the almost smooth and featureless sea bed, they have to feed on the boundary layer. The presence of other substrata such as shipwrecks modifies the pattern of moving waters, thereby altering the selection of fauna according to their feeding type (Baynes & Szmant, 1989; Leichter & Witman, 1997). Varying obstacles ranging from hydroids to seamounts can induce an increased productivity at their peaks/tops due to current acceleration (Hughes, 1975; Genin et al., 1986; Leichter & Witman, 1997).

The biomass on Belgian shipwrecks has a mean value of about 628 g Ash Free Dry Weight.m^{-2} with maximal value peaking at 3,148 g AFDW.m^{-2}. The biomass on hard substrates is on average 85 times larger than on soft sediments from the coastal area. When combining the ratio of biomass on hard substrates and soft sediments with the occurrence of hard substrate, the biomass on artificial structures represents about 4 % of the total biomass from the BCS. This is a gross estimation but nevertheless it proves that the species from artificial habitats can represent a significant part of the biomass in coastal systems.

The general food web organization for shipwrecks and for the surrounding soft-sediments could be quite different. Both depend on exogenous food source but the bioaccumulation of organic matter on soft sediments is partly realized by surface and sub-surface deposit feeder. This step is virtually inexistent on shipwrecks certainly because water movement and turbulence do not favour the deposition of particles (Davoult & Gounin, 1995).

Structure of shipwreck communities

All shipwreck sites are strongly dominated by cnidarians in terms of biomass and by amphipods in terms of abundances.

Three groups of shipwrecks could be determined at varying distance from the coast. These groups are in agreement with the observed abiotic environment described above. The anthozoan *Metridium senile* dominates a species poor community of the coastal sites in association with a more diversified hydroid community dominated by *Tubularia larynx*. This later community has a lower biomass value (102 g AFDW.m^{-2}) and significantly lower species richness compared to the other sites. *Tubularia indivisa* dominates the community of the sites located offshore, with an average biomass of 229 g AFDW.m^{-2}. Intermediate sites are also dominated by *T. indivisa*, but a higher biomass (424 g AFDW.m^{-2}) is observed.

Generally, the percentage of shipwreck surface not covered by epifauna is 30%. Cover is on average high for the sites at an intermediate distance from the coast, medium to high for offshore sites and low for sites close to the coast, probably because of a higher sedimentation rate.

The reasons why the *Metridium senile* community is better thriving in shallower waters may be because either (1) these waters are more productive or (2) because they have a hydrodynamic regime or physical characteristics which favours *M. senile* or (3) because shallow-water gives it an adaptive advantage to its direct competitor which are *Tubularia* spp. The combined effect of increased effect of storms and commonness of *Balanus crenatus* in coastal waters could lead to an increased rate of winter mortality for *T. indivisa* by dislodgment (Hughes, 1983). The openings created may be easily colonized by *M. senile* because its asexual reproduction by pedal laceration and its capability of oriented locomotion make it a very strong competitor for space (Anthony & Svane, 1995). Further, the gamete production of *T. indivisa* in winter is very low and not susceptible to colonize quickly empty spaces (Hughes, 1983).

The community dominated by *T. indivisa* has a high species richness and abundance of organisms. Its species richness varies from 15 in October to 42 in August with a mean value of 33 species per sample. Diversity indices are higher during autumn and winter because of the strong dominance of a few crustacean species. The total density is very high and ranges from 6,500 ind.m^{-2} in October to 445,800 ind.m^{-2} in July, a major part of these individuals being due to the amphipod *Jassa herdmani*. The biomass of the community shows large monthly variation that could result from both biotic and abiotic factors. It varies from 9 g AFDW.m^{-2} in October to 1,106 g AFDW.m^{-2} in July, with *T. indivisa* itself constituting between 59 and 82% of the total biomass. These values are particularly high. Gili & Hughes (1995) noticed that the contribution of biomass from community dominated by hydroids in shallow water may reach 15 to 20 % of the total biomass, but was generally far under.

T. indivisa also offer a support for a diversified set of species. Half of the species, representing the major fraction of the total density of individuals, were directly associated (i.e. attached) with the hydroid. This pattern was also observed on intertidal colonies of *Tubularia crocea* (Genzano, 2001). Proteinaceous and/or polysaccharidic compounds in the perisarc of the hydroid may be responsible for the attraction of a set of species. This has already been demonstrated for scallops with *T. larynx* (Harvey et al., 1995). Schmidt (1983) also explained that the presence of *T. larynx* on experimental panels was favouring the settlement and subsequent rapid domination of ascidian species (*Ciona instestinalis* and *Ascidiella aspersa*). However, Bourget & Harvey (1998) observed on *T. larynx* that various species of juveniles were found at densities up to twenty times more than on other substrata. Following this observation, they showed that the recruitment pattern at scale larger than 3 cm on plastic arborescent structures designed to mimic the hydroid could be explained by passive settlement processes only. It is only at small scale (*ca* 1 mm) that active selection was detected. Consequently, the settlement of species on the shipwreck tubulariids could be the result of the passive flux of larvae from the surrounding water masses, but the acceptation/rejection of the site would be an active mechanism.

We believe that *T. indivisa* is a key species for the epifaunal communities of Belgian shipwrecks because it allows for the development of many other species by providing attachment surface and protection from currents. Another species, the amphipod *J. herdmani* is strongly dependent on the amount of *T. indivisa* which is available. Together, these two species can transfer a large amount of organic and inorganic material from the pelagic compartment to the benthos and consequently be the source of a complex food chain on shipwrecks.

Meiofauna on shipwreck

This study demonstrated that the meiofaunal wreck community of the BCS was characterised by a high abundances of both nematodes and amphipods (juvenile *Jassa herdmani)* Amphipods are regarded as typical macrofaunal, and restricted by their size. Only juveniles can occur in meiofaunal samples, and are as such a component of the non-permanent meiofauna.

In terms of relative abundances, nematodes are, as a group often of utmost importance in meiofaunal samples, both in soft bottom and hard substrate environments (e.g. Heip *et al.,*1985). Comparing genus lists of our wreck communities with those of soft bottom communities, showed no new genera were found for the wreck habitats. A similar conclusion was drawn by Atilla *et al.,*(2003), studying pier pilings, and Danovaro and Fraschetti (2002), studying natural rocky substrates.

Focussing on dominance patterns of the nematode community, it was demonstrated that shipwrecks as a habitat for meiofauna, do differ from soft bottom habitats. The most remarkable features discriminating the wreck meiofauna from soft bottom meiofauna are (1) the high importance of epistrate feeders and selective deposit feeders (in the Kilmore July samples), (2) the abundant occurrence of very large nematode genera.
The first finding will most probably be linked to the nature of the food sources present on the ship shipwrecks, i.e. phytodetrital- rich materials (pers. obs.). Generally soft bottoms are dominated by non-selective deposit feeders (Cattrijsse and Vincx, 2001). Epistrate feeders are more frequently encountered in the upper horizons of sediments, in relation to food availability.
Remarkably, all analysed wreck samples were characterised by the presence of very large 'giant' nematodes. This group of giant nematodes constituted genera like *Anticoma, Deontostoma, Enoplus* and *Pontonema.* Adult lengths, respectively, reach up to 4 mm, 26 mm, 10 mm and 20 mm. As a consequence only juveniles of these genera were observed in our samples and thus the real densities may be largely underestimates. Analysis of macro-epifaunal samples indeed proved the presence of adult organisms in these samples (pers. comm. V. Zintzen). Such giant nematode populations were not observed in the meio-epifauna community studies by Atilla *et al.,*(2003), and Danovaro and Fraschetti (2002). Moreover very large nematodes are frequently observed in deep-sea debris, characterised by sponges and other loosely packed material (pers. comm. I. Demesel).
Enoplus and *Pontonema* both belong to the omnivore/predator group (Wieser , 1953). Predator nematodes are, equivalent to epistrate feeders, more restricted to upper sediment layers in soft bottom environments, due to (1) higher food availability, and (2) loser structure of the substrate, needed for their mobility (Moens *et al.,*2000, Miljutin and Tchesunov 2001). The success of the giant nematodes at our investigated wreck habitats may be primarily related to the structure of the microhabitat, created by the present macrofauna i.e. Anthozoa (Zintzen *et al.,*2006). This may also explain the absence of an influence of the orientation of the substrate on the observed communities. Here again, the orientation of the surface will only indirectly, via the microhabitat created by the macrofauna, determine meiofauna communities.
The difference in meiofauna community between Kilmore and Sperrbrecher 142 is most probably explained by the different macrofauna community present on both shipwrecks. The Sperrbrecher 142 is dominated by *Metridium senile* (Zintzen *et al.,* 2006), an anemone that is considered as producing a toxic mucus. The Kilmore however, is characterised by a more diverse macrofauna community (Zintzen et al 2006). We believe that the monotonous composition at the Sperrbrecher 142, rather than the toxicity of the anemone is a determining factor for meiofauna communities. Nematodes are shown to be highly persistent for toxins e.g. the toxic impact of *Phaeocystis* has no negative effect on nematode communities (pers. comm. J. Vanaverbeke).
In conclusion we found that shipwrecks have an additional value for meiobenthos communities because they create a suitable microenvironment via macro-epifauna communities.

Macrobenthos

Unique species

Although four species were only found in the soft sediments near shipwrecks in the present study, they were not really unique species. The predator *Liocarcinus marmoreus* normally lives on fine sands or gravel and was already found on pebbles from the Belgian waters (Zintzen, in prep.). The frequent occurrence of *L. marmoreus* near shipwrecks can be linked to the higher food availability and the presence of shelter. The crustacean *Photis longicaudata*, the echinoderm *Ophiothrix fragilis* and the polychaete *Tharyx killariensis* were found in only one sample and were not thus representative for all shipwrecks. *Ophiothrix fragilis* is known to live on suitable hard substrata, including bedrock, boulders and on coarse sediment and was already found on pebbles and shipwrecks from the Belgian waters (Zintzen *et al.,* 2006; Zintzen, 2007).

In the present study, both positive or negative influences of the shipwrecks on some nearby soft sediment species occurred. That influence was dependent on the macrobenthic community, which is closely related to the physical habitat (Degraer *et al.,* 1999), and the shipwreck. The depth, size, morphology and physical complexity of the shipwreck could have an influence on the abundances. Ambrose & Anderson (1990) also showed that the densities of the infauna species can be enhanced or depleted in the vicinity of artificial hard substrates. The positively influenced species can benefit in different ways from the presence of shipwrecks. Some species like *Nephtys cirrosa* and *Crangon crangon* benefit from the greater food availability, while others like *Pagurus bernhardus* and *Jassa herdmani* occur as well on soft sediments as on hard substrates and thus have a wider niche to occupy. *Jassa herdmani* is even the most abundant species on pebbles and shipwrecks at the BCS (Zintzen *et al.,* 2006). The negatively influenced species could be affected by changes in predator-prey interactions or physical habitat (Posey & Ambrose, 1994). A possible relation was found between the increasing densities of *Nephtys cirrosa* and the decreasing densities of *Scoloplos armiger.* A significant linear correlation between declining densities of *S.armiger* and increasing densities of *N.cirrosa* was already found by Bamber (1993).

Abra alba, a shallow burrower with a fragile shell, can benefit from the absence of trawling. Bergmann & Santbrink (2000) reported between < 0.5% and 18% mortality of *Abra alba* due to trawling in the southern North Sea.

Physical habitat

The physical habitat was slightly influenced by the presence of shipwrecks. Although the Bourrasque and Sigurd Faulbaums in general had lower median grain sizes compared with their surroundings, a unifying trend between the two shipwrecks could not be shown. The influence on the mud content was the opposite between the two shipwrecks. Thus the influence on the habitat and the impact of the influence is dependent on the shipwreck and his surroundings. Barros *et al.,*(2001) also did not find a consistent trend in sediment parameters between three different reefs.

Community structure

From the dataset of the BCS, Degraer (Degraer *et al.,* 2003; Van Hoey *et al.,* 2004) distinguished between four subtidal communities (the *Macoma baltica* community, the *Abra alba - Mysella bidentata* community, the *Nephtys cirrosa* community and *the Ophelia limacina - Glycera lapidum* community) and three transitional species assemblages. On the basis of multivariate analysis, the similarity between the communities found near shipwrecks and the communities found at the BCS was an obvious trend. A typical "shipwreck" community could not be distinguished. The communities or transitional species assemblages found near shipwrecks were strongly dependent of the shipwrecks and thus dependent of the differences in habitat between shipwrecks. After conducting a thorough comparison of the related community between BCS-samples and shipwreck-samples, differences in global community structure and in abundances of certain species were observed. Those differences were strongly dependent of the community and thus again of the shipwreck. A significant difference in global community structure was only detected for the *Ophelia limacina – Glycera lapidum* community, while differences in abundances of certain species were observed for all studied communities, but without a unifying trend between communities. The abundances of those species were enhanced or depressed near a shipwreck. Some studies (Ambrose & Anderson, 1990; Posey & Ambrose, 1994; Barros *et al.,* 2001) showed a similar trend of increasing or decreasing densities of some species at different distances from a reef (from 1m to even 75m away from a reef). Our study showed that for some species, dependent of the habitat, this trend is commonly found between the infauna of soft sediments near an artificial substrate and far away of such substrates.

At a local scale, a comparison was made between the shipwrecks and their natural surrounding environment. Multivariate analysis showed significant differences in community structure between the shipwrecks and their surroundings. Those differences could again be explained by the significant increase or decrease in abundance of certain species near a shipwreck. A significant effect of communities or transitional species assemblages and a significant combined effect were detected for five species. Thus the influence on their density is strongly dependent on the macrobenthic community or transitional species assemblages, which is closely related to the physical habitat (Degraer *et al.,* 1999), and the presence or absence of shipwrecks. For a second time, this study confirmed that for some species, dependent of the habitat, the trend of decreasing and increasing abundances is commonly found between the infauna of soft sediments near an artificial substrate and further away of such substrates.

The univariate analyses showed no consistent trend in terms of total density. Remarkable was the opposite trend in total density found between the two shipwrecks and their surroundings. The same trend was observed for the mud content. In this manner, those different trends could be caused by differences in physical habitat. Thus the influence on the density is strongly dependent on the shipwreck, its surroundings and the differences in physical habitat. The species richness and N_1-diversity showed a similar trend between the two shipwrecks and their surroundings, although differences between shipwrecks were found. Both indices were slightly higher in the surroundings.

Influence of distance

The substrate near the Sigurd Faulbaums was characterized by medium sandy sediments with low mud contents. The comparison between the two distances showed a higher median grain size close to the shipwreck and a lower median grain size far from the shipwreck. Ambrose & Anderson (1990) found coarser sediments close to reefs and Posey & Ambrose (1994) found finer sediments far from a reef. Barros *et al.,*(2001) found coarser sediments in distance close to and finer sediments further from the rocky reefs. A possible explanation could be that tidal currents might be concentrated around the shipwrecks and local currents could cause the local loss of fine sediments contributing to the dominance of coarse sediments near the shipwrecks (Barros *et al.,* 2001).

Posey & Ambrose (1994) found significantly greater abundances of total infauna far away from a natural reef. On the other hand, Barros *et al.,*(2001) found no consistent trends in terms of the total abundance and diversity at different distances of a reef. Although a small increase in total density was observed at 15 m of the shipwreck, the univariate analyses of this study showed no significant trends in terms of the total density and diversity of communities in soft-sediments at different distances from a shipwreck. Nevertheless, a significant difference in abundances between distances was found for some species. Some species had decreased abundances near the shipwreck, while others had enhanced abundances. Ambrose & Anderson (1990) and Barros *et al.,*(2001) also showed that abundances of some species were increased, but others were decreased around natural and artificial reefs. This trend can explain the differences found in community structure between the distances. Clear evidence of a halo of decreased prey abundances close to the reef, as found by Posey & Ambrose, was not detected. The observed changes could be explained by different factors which act together (Danovaro *et al.,* 2002). Those factors could be the change in the hydrodynamic regime and in the physical characteristics of the sediments, the modification of the distribution and/or composition of the available food sources and the change of the biological interactions between different parts of the food web, like changes in predator-prey interactions.

Some remarks for soft sediments

The trends observed in the present study might be influenced by the different sampling techniques and the temporal variation between samples. The samples of the BCS were collected with a Van Veen grab, while the samples of shipwrecks were collected by a macrobenthos airlift device. The differences between the two techniques are not yet studied.

The influence of temporal effects is already demonstrated. Macrobenthic communities in temperate regions are subjected to a large year-to-year variability of the community structure (Turner *et al.,* 1995). But as long as the main habitat characteristics do not change drastically, the basic composition of the respective communities will remain stable over long periods of time (Govaere *et al.,* 1980; Turner *et al.,* 1995, Van Hoey *et al.,* 2004). In the present study, as well the samples of the BCS as the samples of shipwrecks are collected over a larger period of time. Thus temporal variability could be considered as being inferior to the observed trends.

General conclusion

Results from this research program provided essential knowledge of the biodiversity and biomass of shipwrecks in Belgian marine waters. The influence of abiotic factors on the biodiversity of shipwrecks in Belgian marine waters has been characterized and novel standard protocols for the study and monitoring of fauna of hard substrates have been tested and adapted to the North Sea conditions.

The importance of shipwrecks for the BCS biodiversity has been highlighted as indicated by the particular mieofauna assemblage found in undisturbed sediment close to shipwrecks and by the list of new species to the belgian fauna on shipwrecks.

Shipwrecks have a significant influence on the macrobenthos of the nearby soft-sediments of the BCS. Evidence of influence on community structure was especially found at local scale by comparing the shipwrecks and their surroundings. The influence on community structure can be explained by the enhanced or depressed abundances of certain species near shipwrecks (enhanced e.g. *Nephtys cirrosa*, *Jassa herdmani* and *Abra alba*; depressed e.g. *Spiophanes bombyx, Bathyporeia elegans* and *Scoloplos armiger*). Characteristic species did not occur, but a positive or negative influence of the shipwrecks on some nearby soft sediment species occurred. The physical habitat was slightly, but in general not significantly altered by the presence of the shipwrecks in comparison with their surroundings and the impact was dependent on the shipwreck and his surroundings. At local scale, a difference in median grain size was detected between distances (1 m vs. 15 m). Coarser sediments were present close to the shipwreck, possible due to tidal and local currents. Distance from the shipwreck also had a significant influence on the community structure and infaunal abundances (e.g. *Lanice conchilega, Atylus swammerdami* and *Gastrosaccus spinifer)*. The trend of decreased or increased abundances of certain species close to a shipwreck was also detected between different distances from a shipwreck.

The meiofaunal wreck community of the BCS was characterised by a high abundances of both nematodes and juvenile amphipods (J*assa herdmani)*. Focusing on nematodes as the most dominant group in meiofaunal samples, there were no genera exclusively found for the wreck habitats. Comparing dominance patterns of the nematode community of the wreck communities with those of soft bottom communities, it was demonstrated that shipwrecks, as a habitat for meiofauna, do differ from soft bottom habitats: (1) a higher dominance of epistrate feeders and selective deposit feeders on shipwrecks (in the Kilmore July samples) and (2) the abundant occurrence of very large nematode genera in all analysed wreck samples. A difference in meiofauna community between Kilmore and Sperrbrecher142 was found and is most probably explained by the different macrofauna community present on both shipwrecks. In general we found that shipwrecks have an additional value for meiobenthos communities because they create a suitable microenvironment via the macro-epifauna communities.

This project clearly demonstrates that the shipwreck network along the Belgian coast greatly enhance the biodiversity of hard bottom and acts as stepping stone for hard bottom species to spread over the BCS. As such, this network represents a particular habitat that deserves more attention; in the general context of global change and lost of biodiversity, there is an obvious need for a clear management program (establishment of protected area encompassing shipwrecks) in order to conserve this unique diversity of the BCS.

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Zintzen, V. 2007. Species inventory of shipwrecks from the Belgian part of the North Sea: a comparison with the epifauna on adjacent natural substrates. Pp113-141 in "Biodiversity of shipwrecks from the Southern Bight of the North Sea. PhD Thesis V. Zintzen, 341 p.

Annexe 1

Valoristation of the project: scientific publications, communications and thesis

Peer-reviewed journals

V. Zintzen, Cl. Massin, A. Norro and J. Mallefet. 2006. Epifaunal inventory of two shipwrecks from the Belgian Continental Shelf, *Hydrobiologia*, 555 (1): 207-219.

C. Havermans, C. De Broyer, J. Mallefet, V. Zintzen. 2007. Biological traits and possible dispersal mechanisms of *Jassa herdmani* (Crustacea, Amphipoda) in the North Sea. *Marine Biology*, 153: 83-89.

V. Zintzen, A. Norro, Cl. Massin and J. Mallefet. In Press. Spatial variability of epifaunal communities from artificial habitat: shipwrecks in the Southern Bight of the North Sea, *Estuarine, Coastal and Shelf Sciences*.

V. Zintzen, A. Norro, Cl. Massin and J. Mallefet. In Press. Temporal variation of *Tubularia indivisa* (Cnidaria, Tubulariidae) and associated epizoites on artificial habitat communities in the North Sea. *Marine Biology*. (Accepted on 07 September 2007).

V. Zintzen and F. Kerckhof. The sponge inhabiting barnacle *Acasta spongites* (Poli, 1795) (Crustacea, Cirripedia), a new record for the southern North Sea: how artificial habitats may increase the range of a species. *Belgian Journal of Zoology*. (Accepted on 24 July 2007)

Papers submitted to peer-reviewed journals

V. Zintzen, Cl. Massin. Impact of artificial hard substrates on the distribution range of species. *Journal of the Marine Biological Association of UK*.

O.T. Crawford, S. Degraer, J. Mallefet and V. Zintzen. Macrobenthos of shipwrecks within and around the Belgian waters as a potential food resource for fish populations. *Belgian Journal of Zoology*.

Steyaert M, Lammertyn M, Vincx M and Degraer S. Meiofauna communities on ships shipwrecks of the Belgian Continental Shelf

De Maersschalck V., Vincx M. and. Degraer S.. Effects of shipwrecks on the infauna of the nearby soft-sediments (Belgian Continental Shelf). *Estuarine, Coastal and Shelf Sciences*.

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V. Zintzen. 2005. Les amphipodes tubicoles des épaves du plateau continental belge. De Strandvlo, 25(2): 38-49.

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V. Zintzen. 2004. Faunal diversity on shipwrecks: first results for the Belgian Continental Shelf. PhD students in ecology meeting day, 2nd of June 2004, Sainte-Marie, Belgium.

V. Zintzen, Cl. Massin, A. Norro and J. Mallefet. 2004. Faunal diversity on shipwrecks, first results for the Belgian Continental Shelf. Proceedings of the 10th Benelux Congress of Zoology, Leiden University, the Netherlands, pp 152.

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V. Zintzen, Cl. Massin, A. Norro and J. Mallefet. 2005. Description and implications of unplanned artificial reefs: shipwrecks in the Southern Bight of the North Sea (Belgium). Proceedings of the 8th International Conference on Artificial Reefs and Artificial Habitats, 10-14th of April 2005, Biloxi, USA, pp 80.

V. Zintzen. 2006. L'importance des épaves pour la biodiversité des eaux marines belges. Journée d'étude: Les épaves, éternelles ou perdues à jamais? Organisé par le Centre de Coordination pour la Gestion Intégrée du Littoral Belge, à la demande du SPF Environnement et en collaboration avec l'Unité de Gestion du Modèle Mathématique de la Mer du Nord et l'Institut Flamand du Patrimoine Immobilier. Ostende, le 20 Juin 2006.

V. Zintzen, E. Vandenberghe, S. Degraer, A. Norro et J.Mallefet. 2007. Epaves de la Mer du Nord: zones de haute diversité biologique. Proceedings de 'To sea or not to sea', 2ème colloque international sur l'archéologie maritime et fluviale dans la zone sud de la mer du Nord et de l'exposition 'Passé submergé', Bruges, 21-23 septembre 2006, pp 80-83.

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<u>Poster presentations</u>

V. Zintzen. Epifauna of shipwrecks in Belgium. Exchange program with the Natural History Museum of London, 7thof july 2003, Royal Belgian Insitute of Natural Sciences.

V. Zintzen, Cl. Massin, A. Norro and J. Mallefet. Importance of shipwrecks for the biodiversity of the Belgian Continental Shelf. 38th European Marine Biology Symposium, 6-13th of September 2003, Aveiro, Portugal.

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De Maersschalck V., Vincx M. and. Degraer S.. Artificiële substraten verhogen de predatiedruk in de natuurlijke, aangrenzende zachte substraten. Studiedag Wrakmanschap of eeuwig verloren? Oostende, België: 20 juni 2006.

Thesis

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Havermans C. (2006) : Dissemination of *Jassa herdmani* (Amphipoda, Ischyroceridae) between spots of artificial hard substrates. Master of Science, UCL, Belgium

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Matthew Lammertijn, (2005). Leven op en rond scheepswrakken in het Belgisch continentaal plat.. Licentiaatsthesis, UGent.

Annexe 2

List of available CTD profiles including date, time of the profile, name of the visited wreck and Secchi disk measurement

date	ctd	Secchi	wreck	time
2/04/2004	1		klm	13:49
2/04/2004	1		klm	8:55
26/07/2004	1		klm	11:10
26/07/2004	1		wes	15:25
10/08/2004	1	6	bou	14:13
11/08/2004	1	6	wes	17:07
16/09/2004	1		bir	7:58
8/10/2004	1		bou	
8/10/2004	1		klm	
2/12/2004	1	0.9	wes	13:46
18/03/2005	1	3	klm	13:40
2/05/2005	1	9	bir	15:25
3/05/2005	1	11	klm	14:16
3/05/2005	1		wes	16:19
4/05/2005	1		wes	9:15
4/05/2005	1	9	bou	15:49
18/05/2005	1	9	bir	12:30
3/06/2005	1	10.5	ddn	10:11
3/06/2005	1	6	lst	15:42
17/06/2005	1	9.5	cal	7:42
27/06/2005	1	10.5	gdc	11:38
28/06/2005	2	10	jnm	12:45
29/06/2005	2	8	lct	10:46
17/08/2005	2	7	klm	10:38
30/08/2005	1	2	lst	13:02
12/09/2005	1	3.5	klm	16:44
27/10/2005	1	3	lst	11:38
27/10/2005	1	10	klm	13:31
24/11/2005	1	2.5	bou	8:52
8/03/2006	1	1,6	bou	12:56
24/03/2006	1	3.5	bir	12:58
6/04/2006	1	3.5	klm	14:25
11/05/2006	1	10	klm	12:41
11/05/2006	1	7.5	cal	17:12
8/06/2006	1	12	cal	9:44
8/06/2006	1	12+	klm	14:27

BEWREMABI available CTD casts. Secchi disk measurements are in m. cal for Callisto, ddn for Duc De Normandie, gdc for Garden City, lst for LST420, jnm for John Mahn, wes for Westebroeck, klm for Kilmore, bou for Bourrasque bir for Birkenfels and lct for LCT457.

Annexe 3

Diving activities during BEWREMABI project

Table A3-1. Name of the logistic responsible, i.e. the scientist in charge to organize oxygen delivery *on board* of ship, to contact all the participants (divers, technicians and the ship responsible), before each fieldtrip. This table highlight the role played by RBINS scientists

Year 2004 : 10 field trips

Date	19/02	14/03	30/03	02/04	27/05	26/07	10-11/08	13-17/09	02/10	02/12
Resp.	Massin	Massin	Massin	Massin	Massin	Massin	Massin	Norro	Massin	Massin

Year 2005 :16 field trips

Date	12/01	04/03	18/03	18/04	02-04/05	18/05	2-3/06	13-17/06	27-29/06	17/08
Resp	Massin	Massin	Massin	Hernandez	Massin	Massin	Massin	Norro	Massin	Massin
Date	30/08	12-16/09	13-14/10	27-28/10	10/11	24-25/11				
Resp.	Massin	Norro	Massin	Massin	Zintzen	Massin				

Year 2006 : 8 field trips

Date	08/03	24/03	06-07/04	11/05	08/06	21-23/06	03-06/07	06/09
Resp.	Massin	Massin	Massin	Norro	Norro	Norro	Norro	Norro

Table A3-2: R.V. Zeeleeuw plan during BEWREMABI project (2004-2006)

Cruise Nr	Date	Wreck(s) visited	Cruise Nr	Date	Wreck(s) visited
04-561	10-Aug-04	Bourrasque	05-391	17-Aug-05	Killmore
					LST420 - Queen of the channel
	11-Aug-04	LCTR457 - Westerbroek	05-412	30-Aug-05	Cancelled
04-640	21-Oct-04	Cancelled	05-450	26-Sep-05	Cancelled
04-720	2-Dec-04	Cancelled		27-Sep-05	Cancelled
04-760	22-Dec-04	Cancelled		28-Sep-05	Cancelled
	23-Dec-04	Cancelled	05-480	13-Oct-05	Cancelled
05-010	4-Jan-05	Cancelled		14-Oct-05	Cancelled
	5-Jan-05	Cancelled	05-520	27-Oct-05	Killmore
05-030	18-Jan-05	Cancelled		28-Oct-05	Cancelled
	19-Jan-05	Cancelled	05-530	10-Nov-05	Cancelled
05-060	3-Feb-05	Cancelled	05-580	24-Nov-05	Bourrasque
	4-Feb-05	Cancelled		25-Nov-05	Cancelled
05-110	4-Mar-05	Cancelled	06-150	8-Mar-06	LST420 - Bourrasque
04-150	17-Mar-05	Cancelled		9-Mar-06	Bourrasque
	18-Mar-05	Killmore	06-210	24-Mar-06	Birkenfels
05-210	18-Apr-05	Cancelled	06-270	6-Apr-06	Killmore
05-260	2-May-05	Birkenfels		7-Apr-06	Cancelled
	3-May-05	Killmore	06-360	11-May-06	Killmore - Bourrasque
	4-May-05	Westerbroek - Bourrasque	06-420	8-Jun-06	Callisto - Killmore
05-290	18-May-05	Birkenfels	06-430	21-Jun-06	Sigird Faulbaums
05-320	1-Jun-05			22-Jun-06	Bourrasque
	2-Jun-05	Duc de Normandie		23-Jun-06	LCTR457 - Bourrasque

	3-Jun-05	Duc de Normandie - LST420	
05-370	27-Jun-05	Garden City - Basilisk/Hayburn	
	28-Jun-05	John Mahn	
	29-Jun-05	LCTR457	
	30-Jun-05	Cancelled	

Remarks about diving safety

Out of the 49 fields trips totalizing 288 man-dive for the sampling, only two incidents have been reported. One was concerning a diver short of air after adapting the dive plan to extend bottom time out of the no-decompression limit. Spare thank has been provided by the safety diver at the surface and procedure applied without any outcome. The second concerning a thumb injury when the diver transferred from RIB to main Research Vessel. This was not really diving incident.

Annexe 4

Abiotic data table and values for the different studied sites
For each shipwreck, graphs and tables of abiotic data are provided when they are all available; the data obtained are presented in the following order:

1. Graph of BMDC/IMERS data for salinity, temperature and turbidity
2. Elementary statistics of theses parameters.
3. Table of monthly means temperature and salinity from R/V Belgica underway data,
4. some CTD graphs
5. Graph of the total suspended matter derived from SeaWifs satellite data.
6. Graph of current velocity, direction…

LCTr 457
(WGS84 N 51°14',964 E 002°33',026)

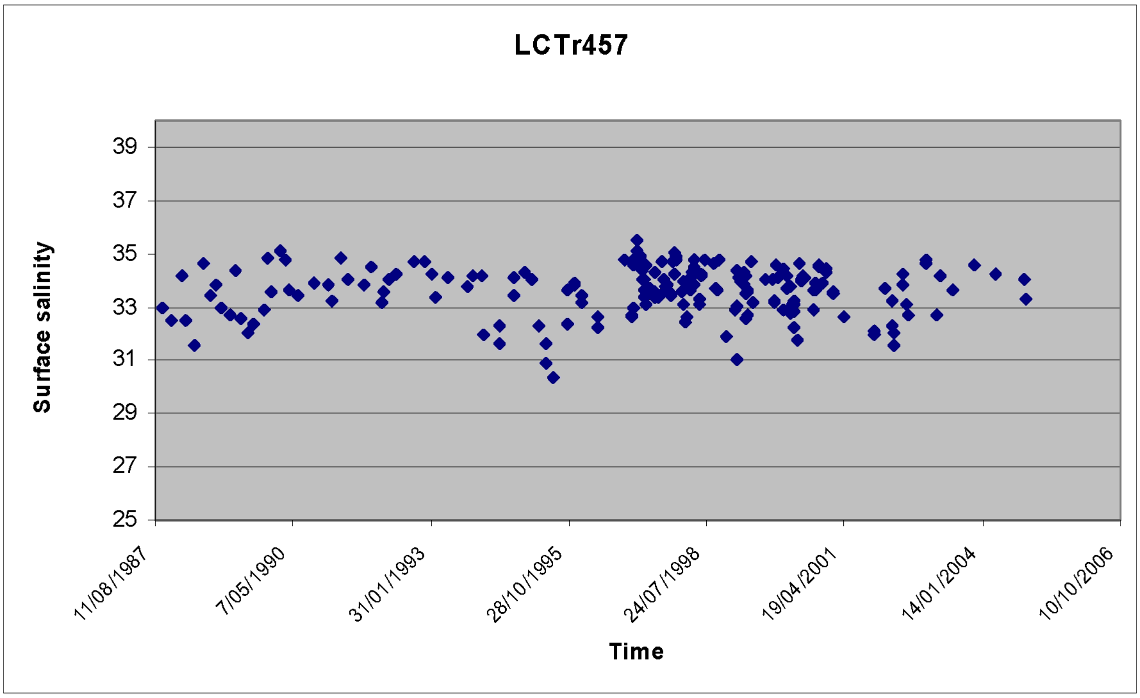


Figure A4-1: Surface Salinity. Station LCTr457 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

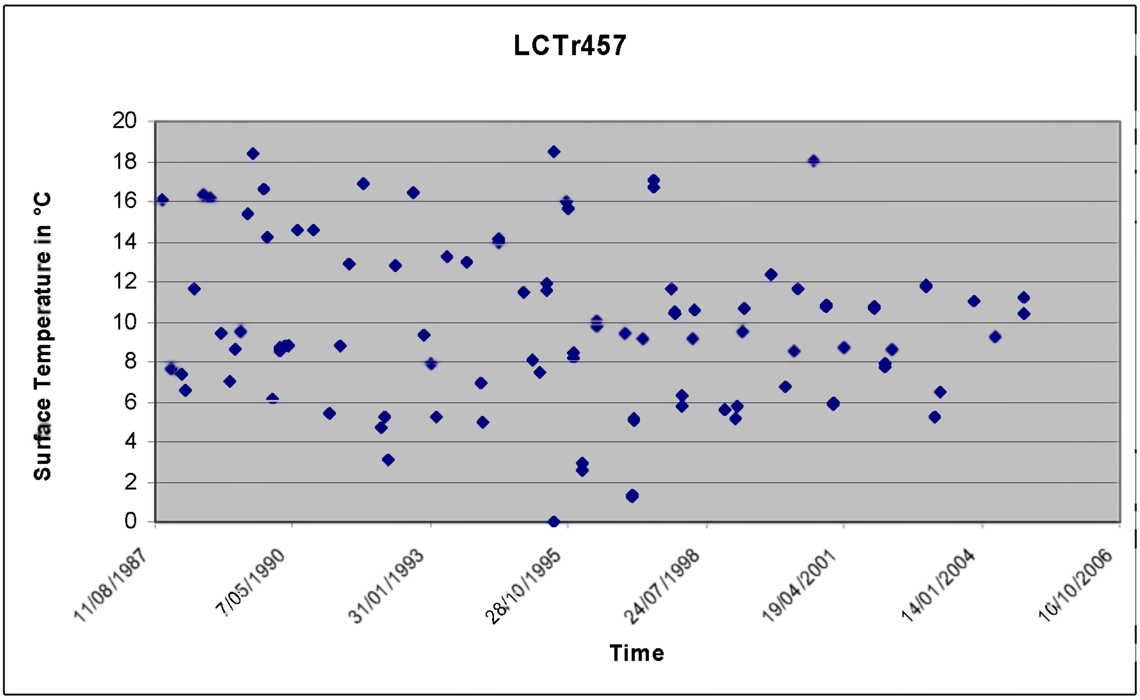


Figure A4-2: Surface Temperature. Station LCTr457 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

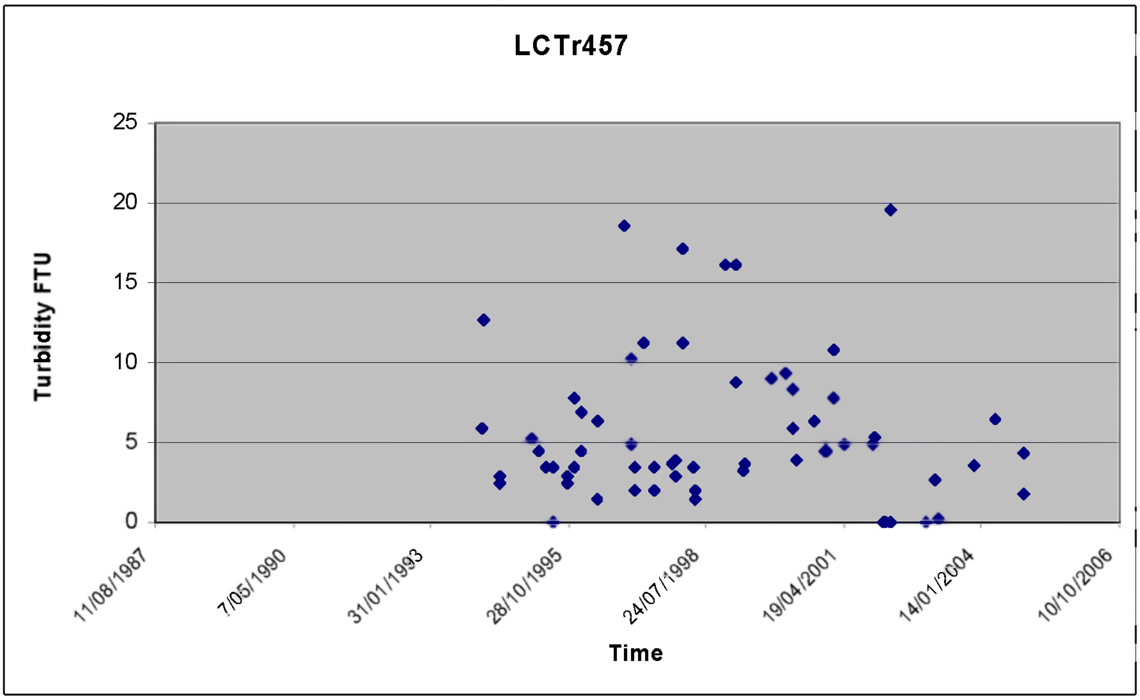


Figure A4-3: Turbidity. Station LCTr457 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

lct457	salinity	temp	turbidity
mean	33.63	9.88	6.08
std	0.90	3.93	4.50
min	30.39	1.23	0.25
max	35.50	18.52	19.54
mediane	33.75	9.40	4.40
number	202		

Table A4-1: Elementary statistics for station LCTr457 from BMDC (Mumm) and IMERS (Vliz) data

LCT 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	2.48	6.42	4.29	29.34	33.45	32.12	2.05	
2	1.25	11.13	6.33	30.26	34.52	33.58	2.19	0.32
3	2.54	8.73	6.80	28.12	34.48	32.81	1.74	1.01
4	6.90	10.69	8.66	29.86	34.81	33.29	0.78	0.92
5	9.18	14.81	11.85	30.46	34.72	33.30	1.26	0.96
6	12.11	18.58	14.90	31.41	34.71	33.71	1.10	0.23
7	15.75	19.31	17.20	30.73	34.89	33.38	0.74	0.72
8	17.58	22.09	19.67	31.65	34.91	33.64	1.06	0.33
9	14.90	19.96	17.66	32.23	35.41	33.78	1.19	0.59
10	10.87	17.48	15.27	31.25	34.93	34.09	0.74	0.55
11	8.42	14.36	11.54	30.91	34.88	33.77	0.73	0.90
12	5.57	12.58	8.97	31.47	34.89	33.42	1.57	0.90

Table A4-2: LCTr457 monthly mean temperature T21 and salinity S21 from R/V Belgica underway data (1993-2006) Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

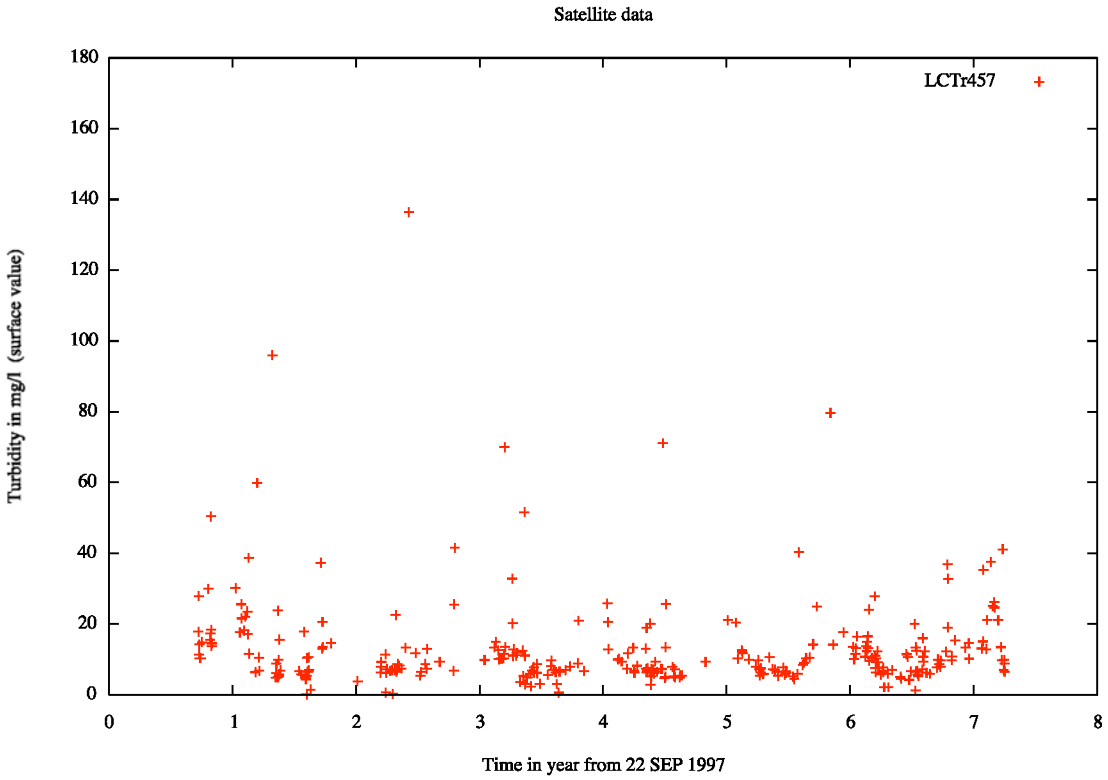
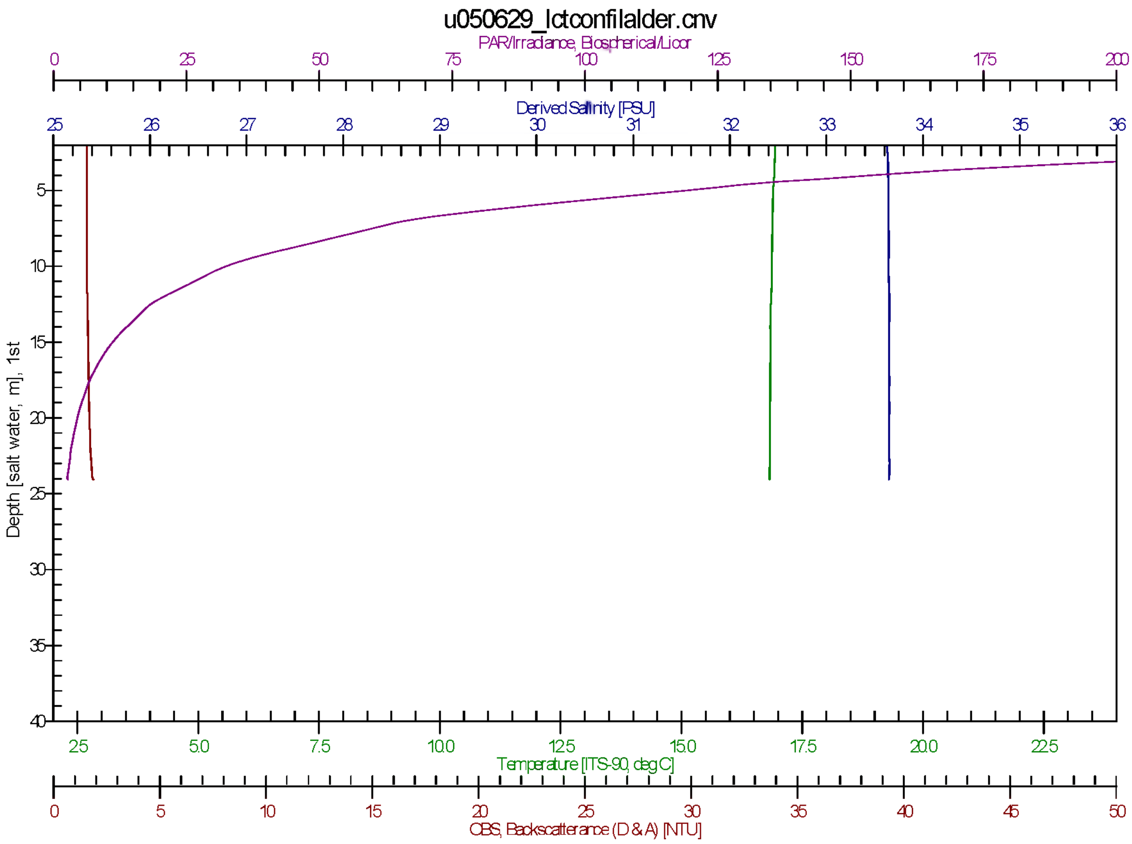


Figure A4-4: Total suspended matter in mg/l for station LCTr457. Data derived from SeaWifs 670 nm band



LCT 457 wreck. Date: 15 September 2004 HW at Oostende 02:23 and 14:34 (UT+2)

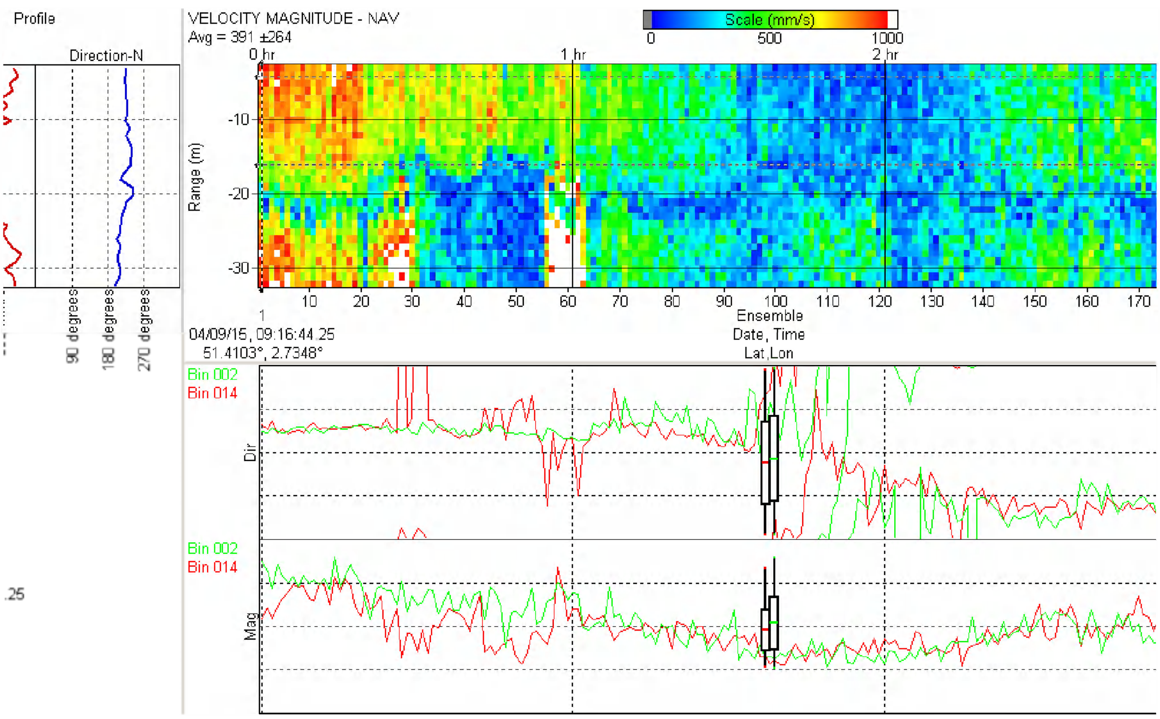


Figure A4-5

Birkenfels
(WGS84 N 51°38',989 E 002°32',268)

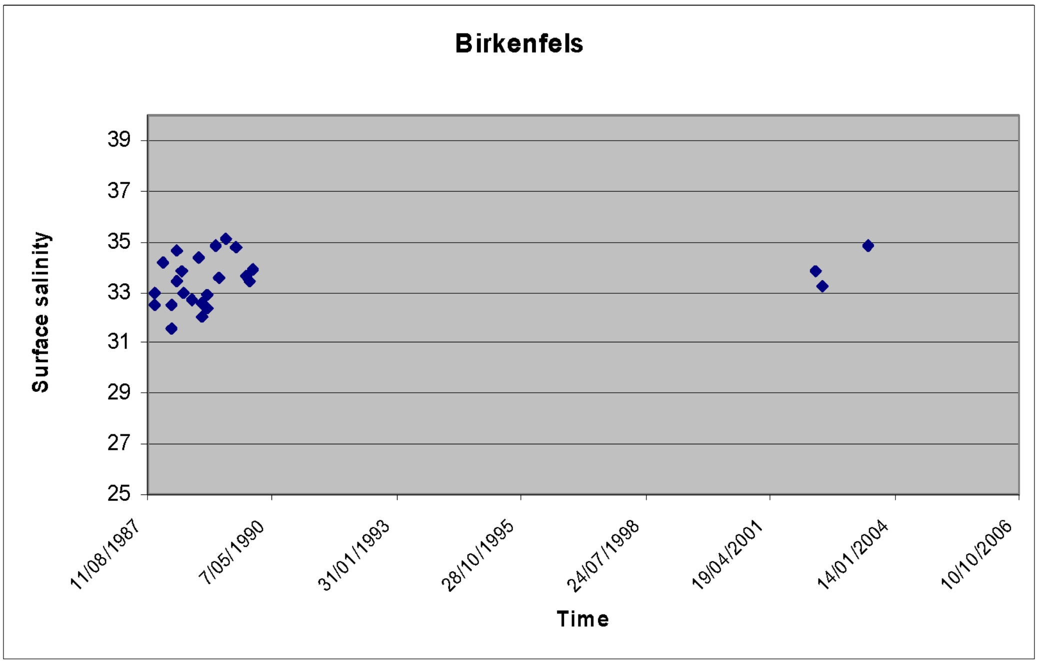


Figure A4-6: Surface Salinity. Station Birkenfels from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

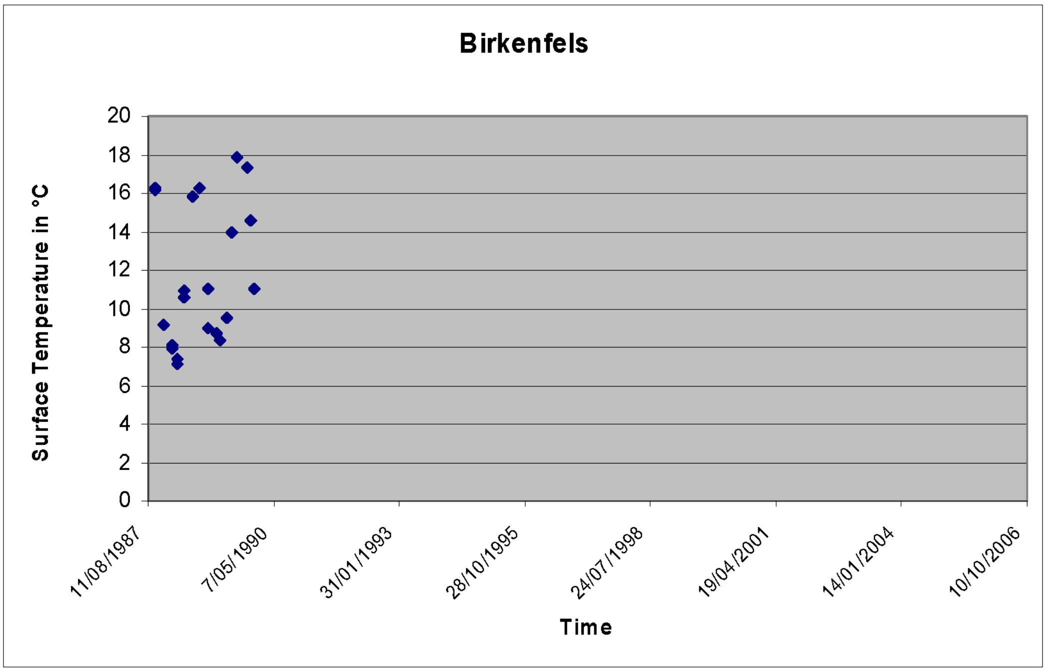


Figure A4-7: Surface Temperature. Station Birkenfels from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

Birkenfels	Salinity	Temp.
mean	34.55	11.52
std	0.37	3.52
min	33.65	7.09
max	35.24	17.90
mediane	34.58	10.89
number	29	

Table A4-3: Elementary statistics for station Birkenfels Remark, no turbidity data available from database from BMDC (Mumm) and IMERS (Vliz) data

BIR 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	5.14	6.63	5.87					
2	6.12	8.95	7.70				1.60	
3	4.71	8.17	7.10	33.51	34.94	34.44	1.48	0.52
4	8.29	9.46	8.87	33.35	35.25	34.65	0.44	0.63
5	9.54	12.98	10.92	34.82	35.08	34.95	1.47	0.11
6	12.69	15.08	13.61	34.44	35.33	34.75	0.69	0.09
7	14.97	16.96	15.80	34.33	34.83	34.63	0.64	0.20
8	17.08	20.01	18.61	33.88	35.15	34.60	0.88	0.37
9	16.61	19.72	18.08	34.02	35.01	34.53	0.89	0.27
10	14.09	17.41	15.60	32.61	34.96	34.64	1.17	0.24
11	9.21	15.39	12.94	33.85	35.10	34.57	1.63	0.49
12	8.32	13.31	11.43	34.73	35.01	34.91	1.34	0.01

Table A4-4: Birkenfels monthly mean temperature and salinity from R/V Belgica underway data (1993-2006) Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

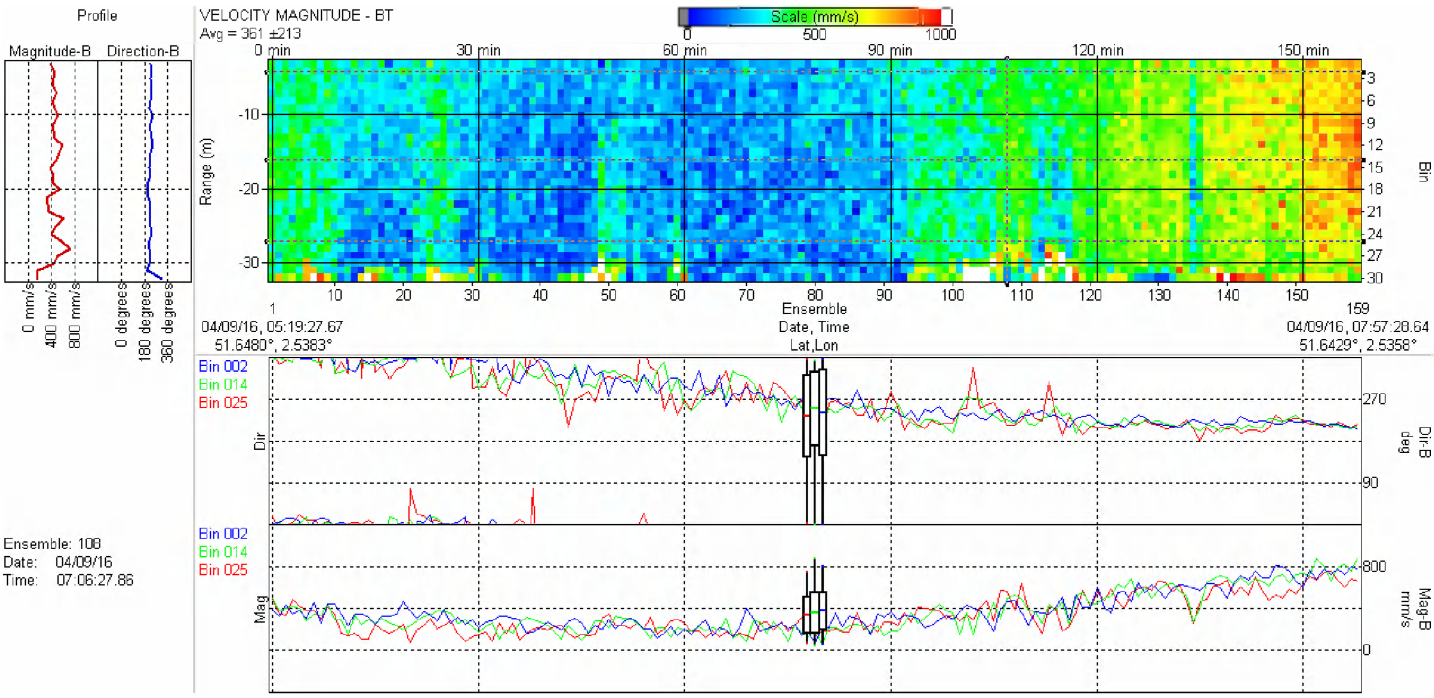


Figure A4-8: Birkenfels wreck Date:16 September 2004 HW at Oostende at 02:53 and 15:06 (UT+2).

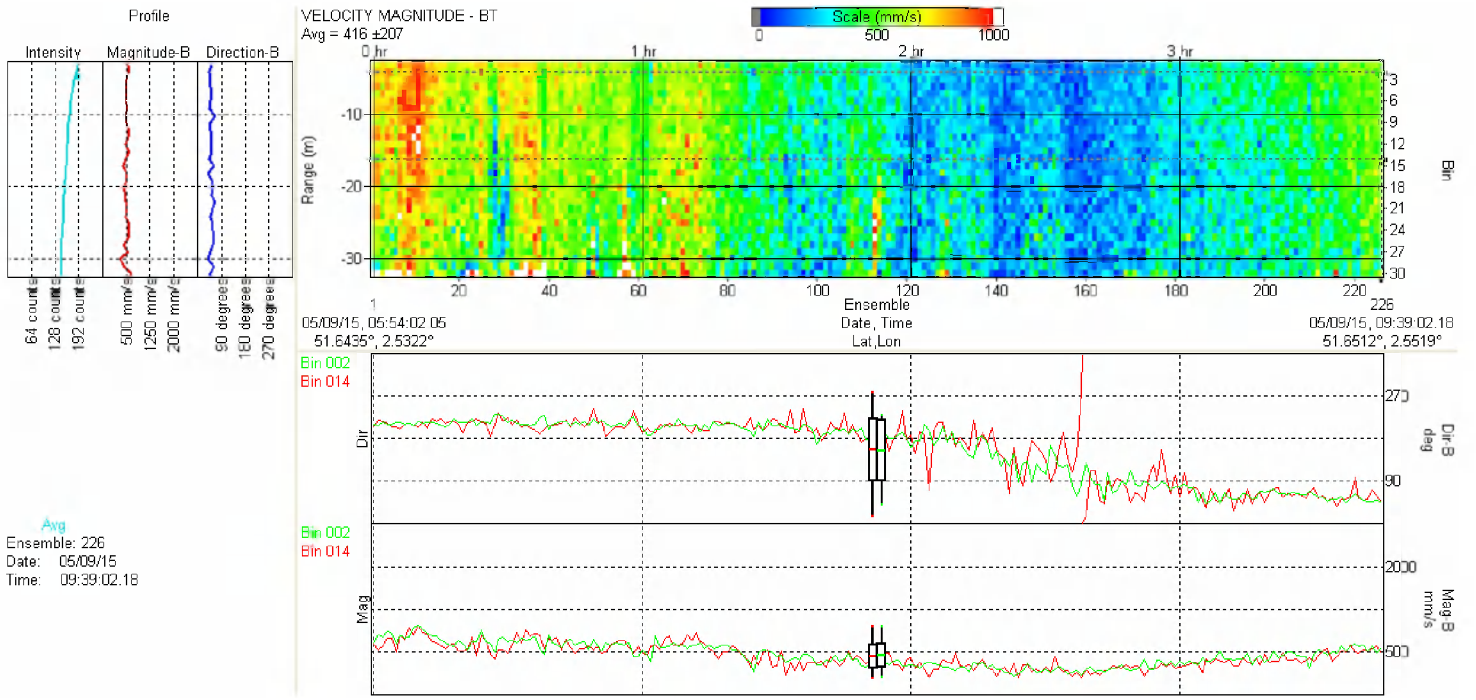


Figure A4-9: Birkenfels wreck. Date 15 September 2005 HW at Oostende 11:46 and 00:15 D+1 UT+2)

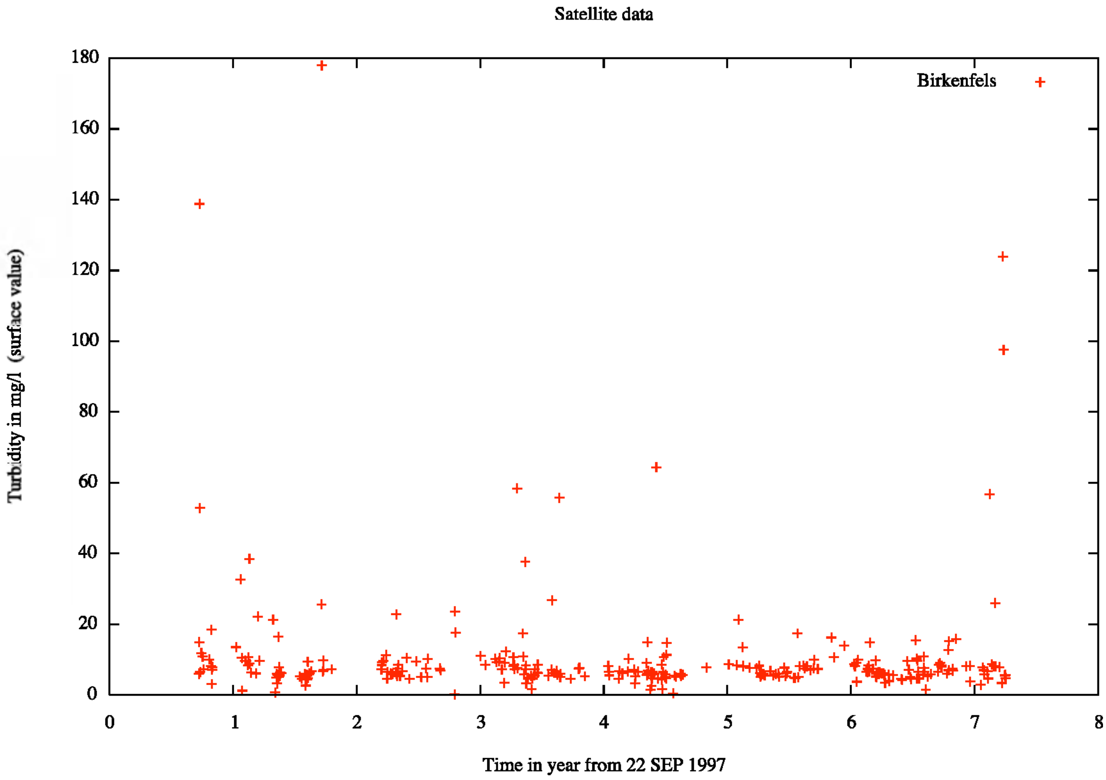


Figure A4-10: Total suspended matter in mg/l for station Birkenfels. Data derived from SeaWifs 670 nm band

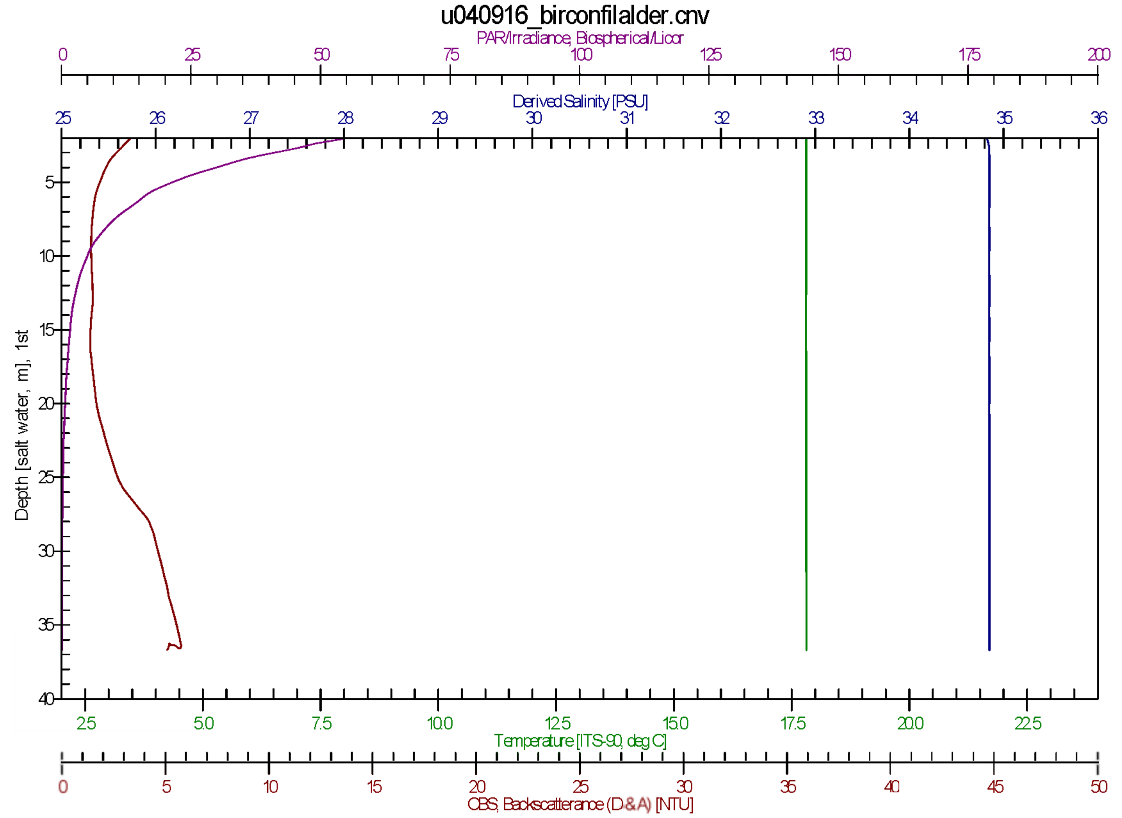


Figure A4-11

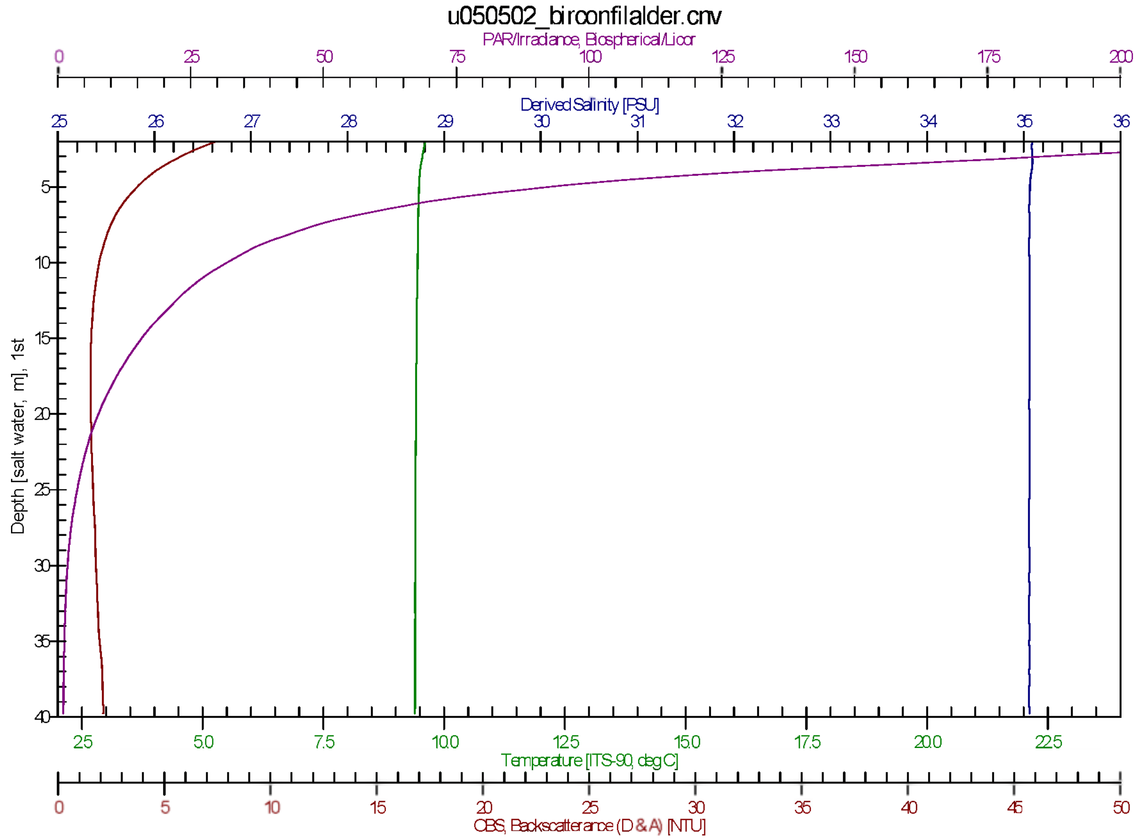


Figure A4-12

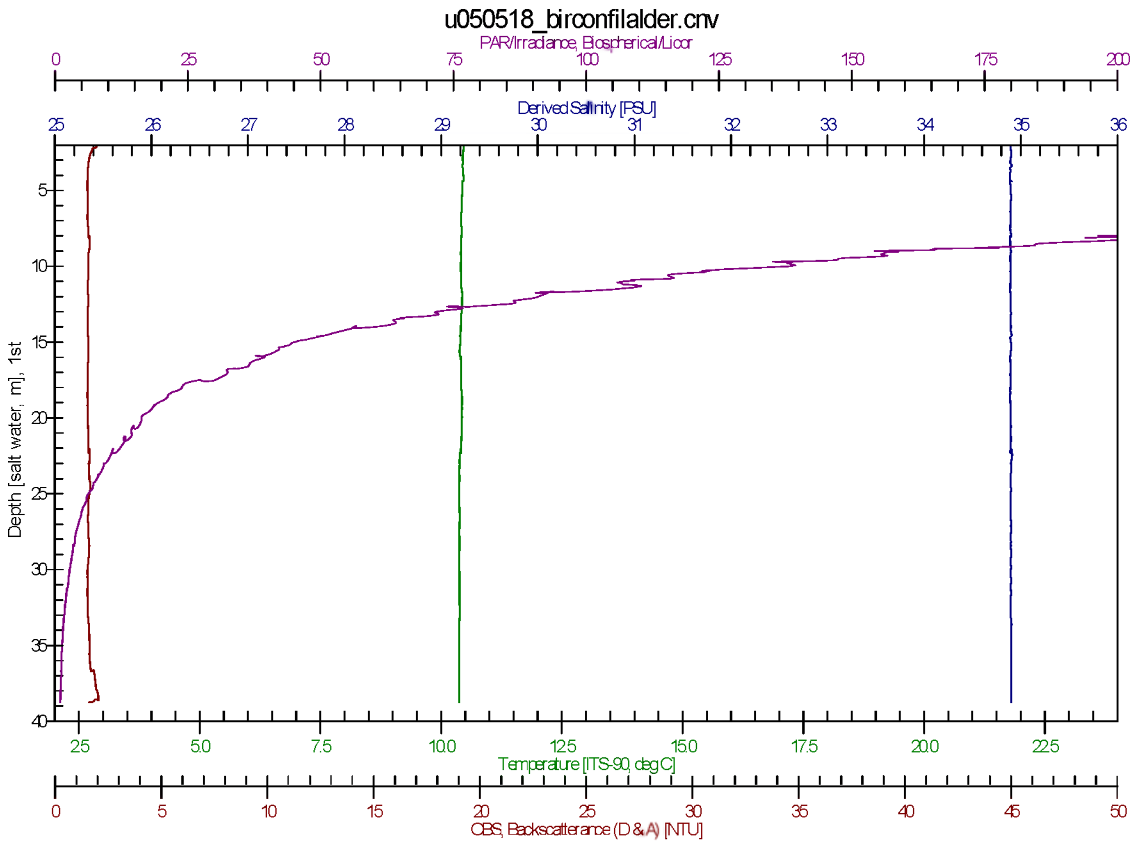


Figure A4-13

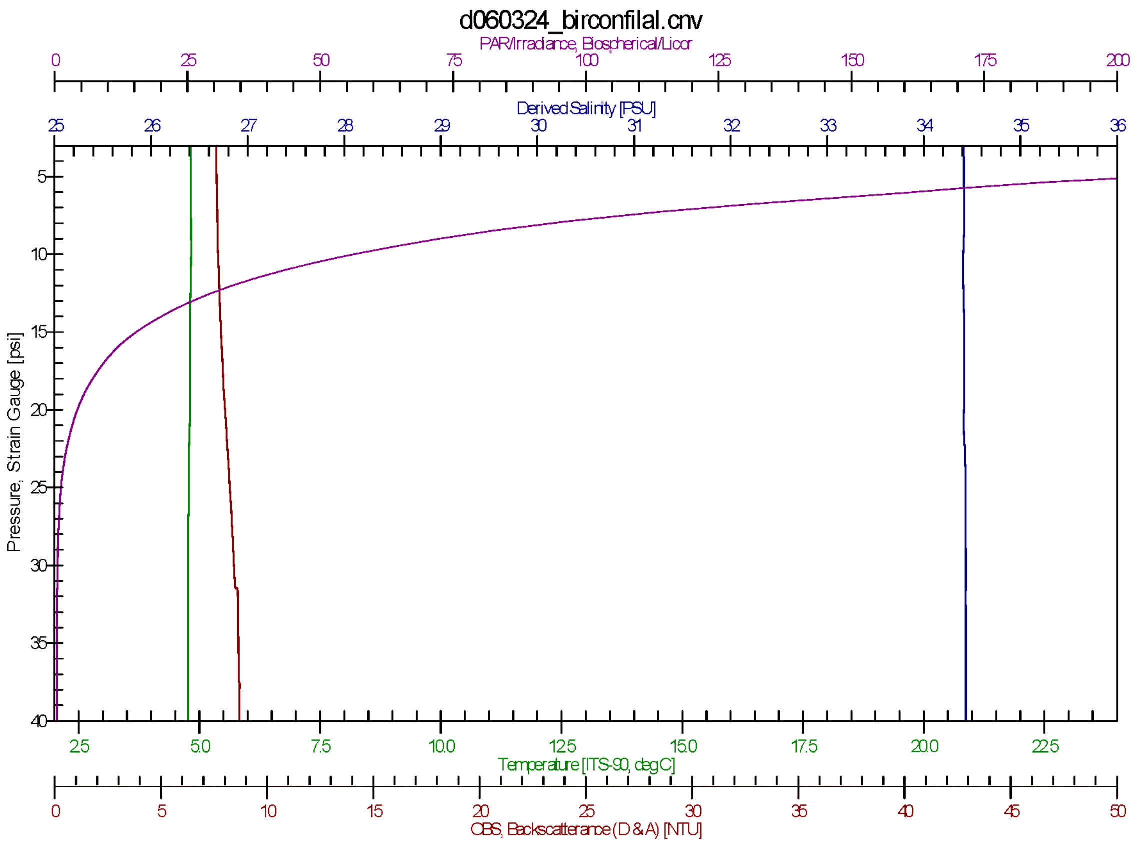


Figure A4-14

Bourrasque
(WGS N 51°14',964 E 002°33',026)

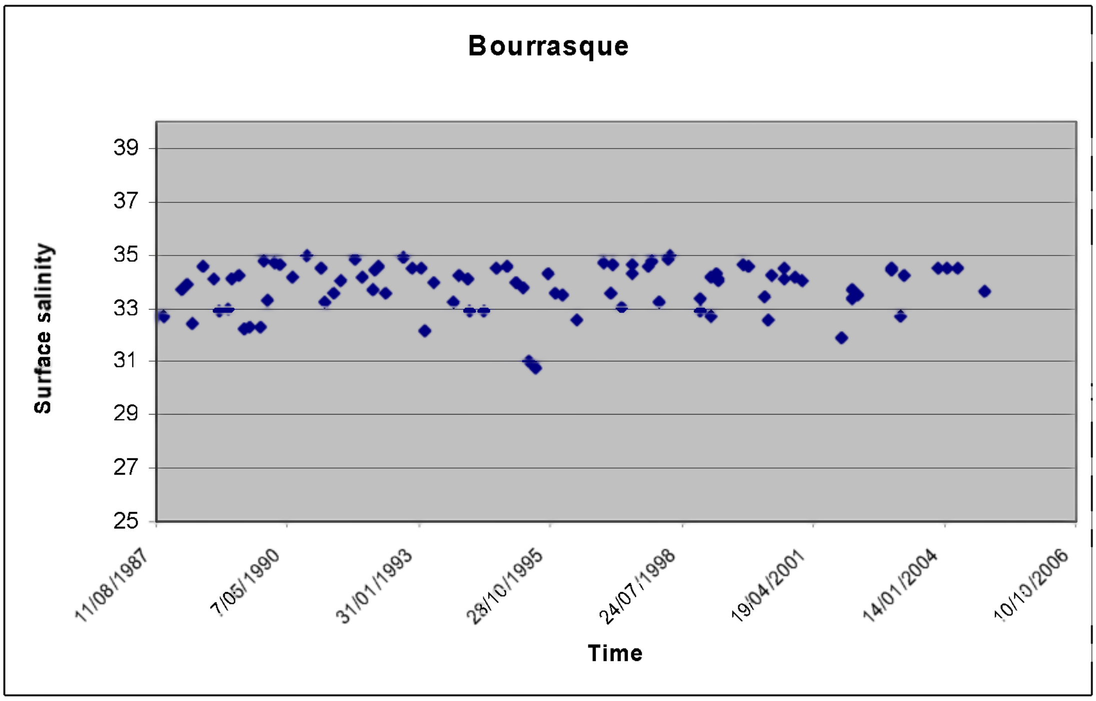


Figure A4-15: Surface Salinity. Station Bourrasque from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

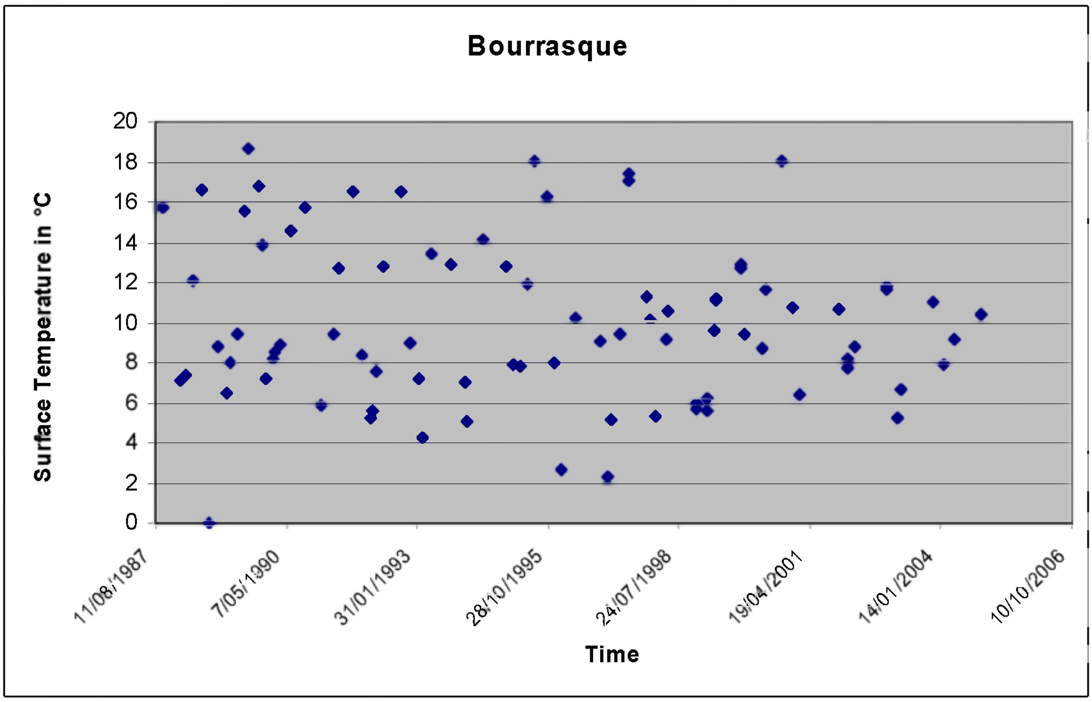


Figure A4-16: Surface Temperature. Station Bourrasque from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

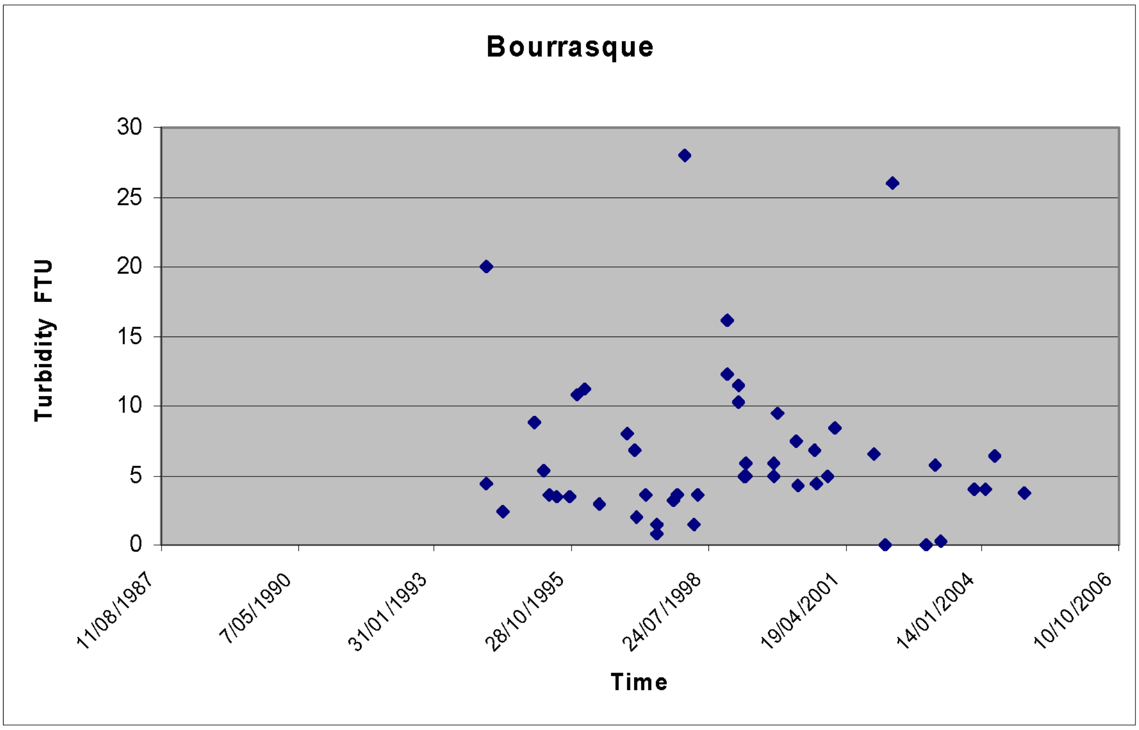


Figure A4-17: Turbidity. Station Bourrasque from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

Bourrasque	Salinity	Temp.	Turbidity
mean	33.81	10.23	6.91
std	0.88	3.91	5.83
min	30.74	2.33	0.26
max	34.98	18.70	28.00
mediane	34.10	9.41	4.89
number	92		

Table A4-5: Elementary statistics for station Bourrasque from BMDC (Mumm) and IMERS (Vliz) data

BOU 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	1.12	6.22	4.36	30.51	33.21	31.63	1.28	
2	1.61	8.98	5.94	30.24	34.13	32.51	2.13	0.92
3	2.60	9.26	6.84	29.90	34.70	32.99	1.78	1.01
4	6.95	11.36	9.03	29.66	35.09	33.55	0.89	1.32
5	9.71	15.29	11.84	31.21	34.53	33.72	1.23	1.17
6	13.50	17.86	14.97	33.20	34.85	34.36	0.55	0.28
7	15.67	19.49	16.97	32.35	34.86	34.12	0.65	0.52
8	17.97	21.80	19.68	32.91	34.95	33.98	1.01	0.47
9	14.44	20.25	17.49	31.11	34.85	34.08	1.03	0.86
10	10.87	17.46	15.08	31.49	34.98	33.98	0.80	0.42
11	8.70	13.15	10.88	30.32	34.98	33.71	0.55	0.99
12	3.89	12.17	8.66	30.69	34.78	33.80	2.05	0.84

Table A4-6: Bourrasque: monthly mean temperature and salinity from R/V Belgica underway data (1993-2006) Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

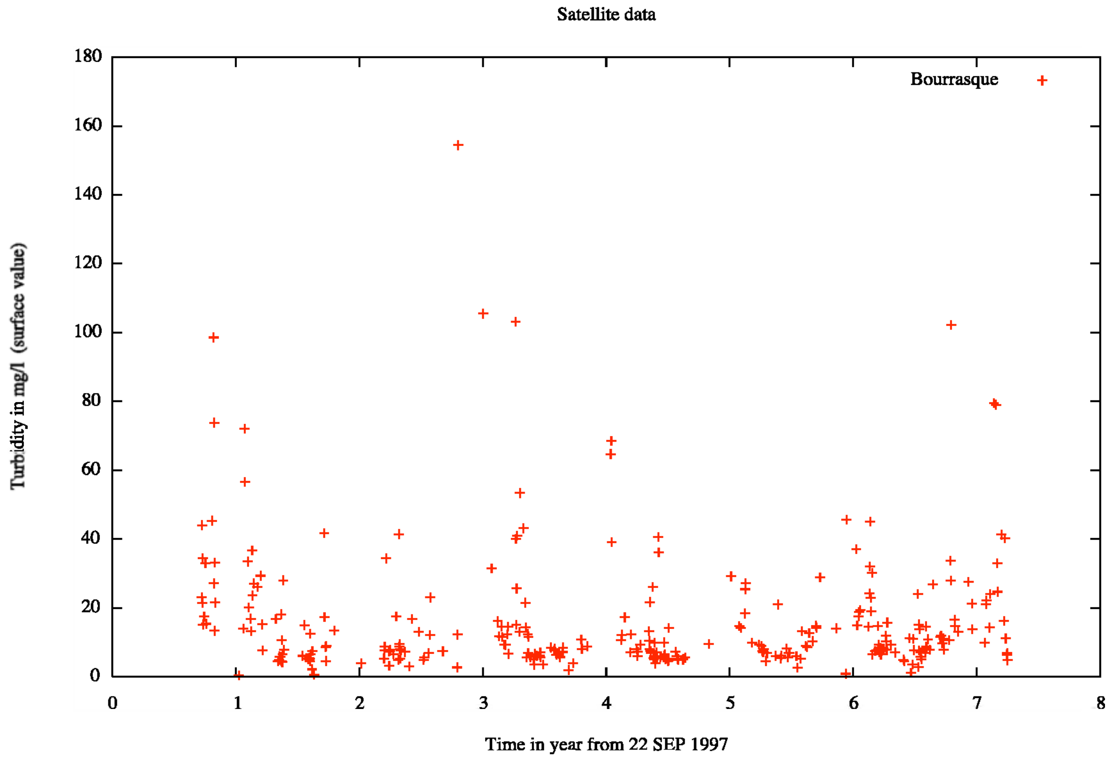


Figure A4-18: Total suspended matter in mg/l for station Bourrasque. Data derived from SeaWifs 670 nm band

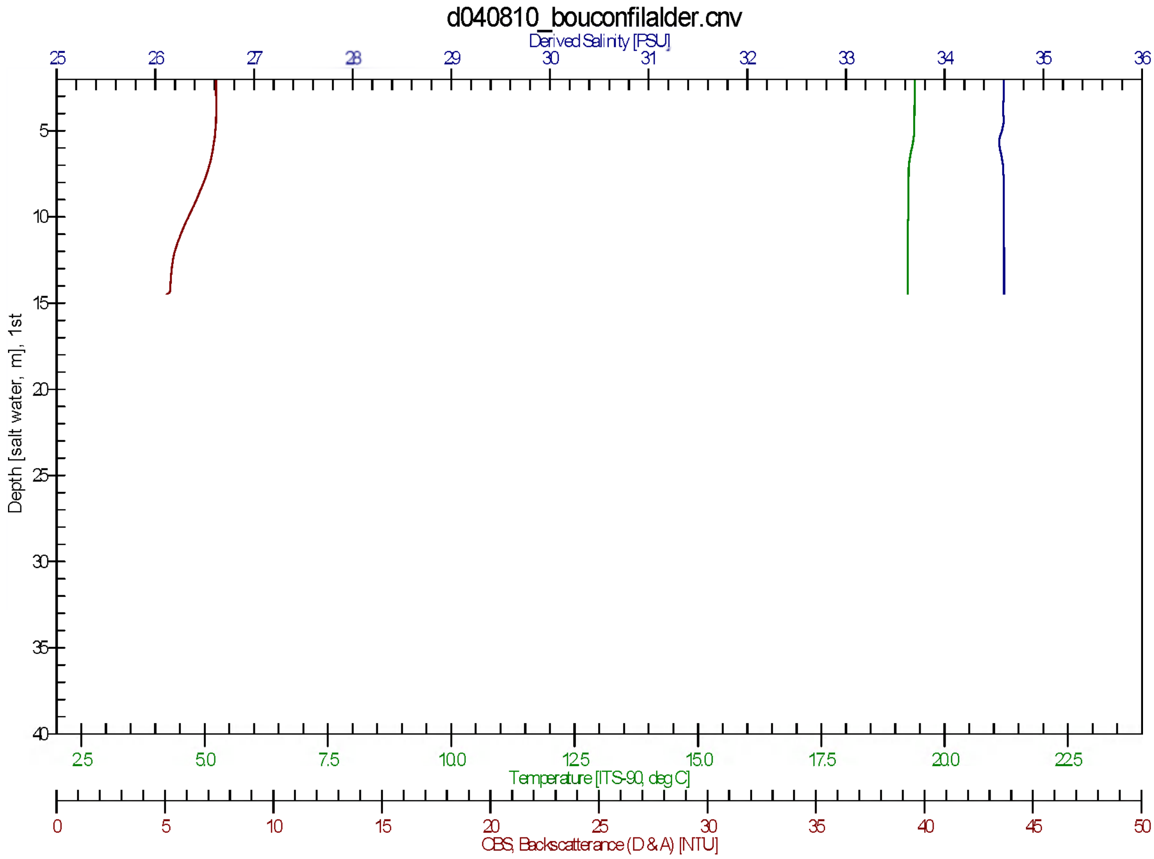


Figure A4-19

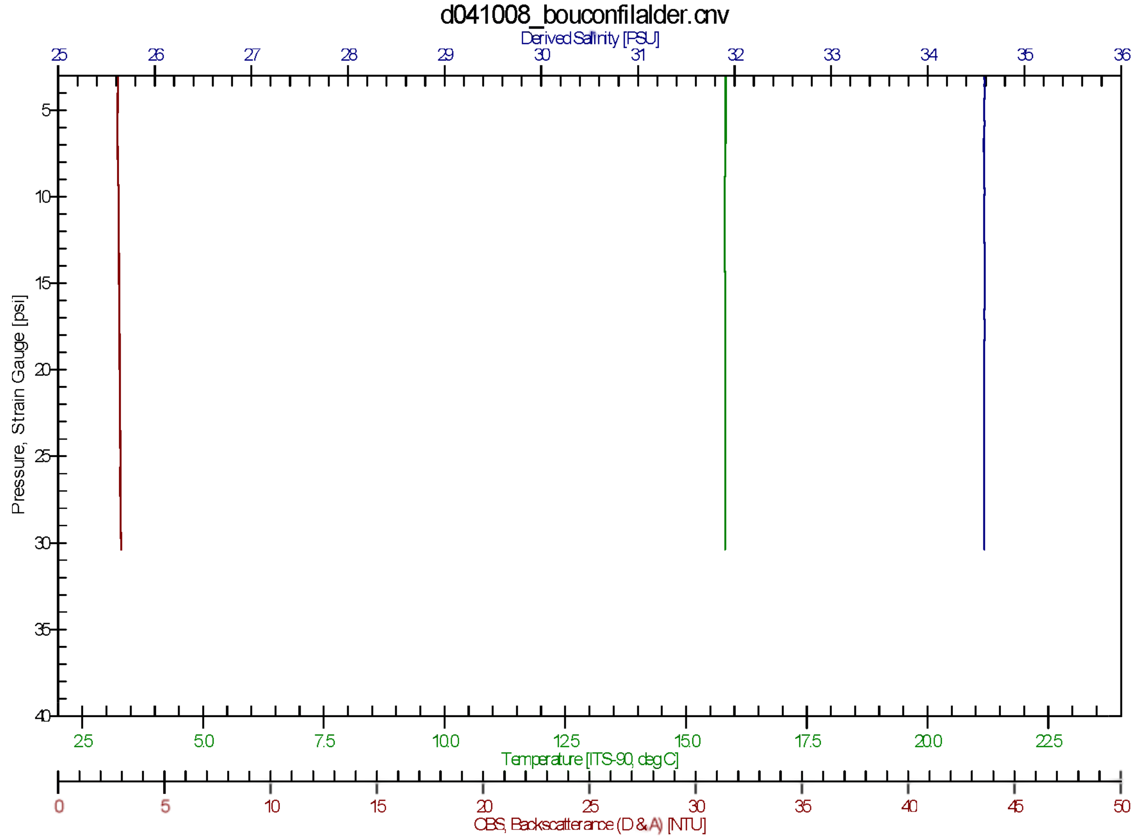


Figure A4-20

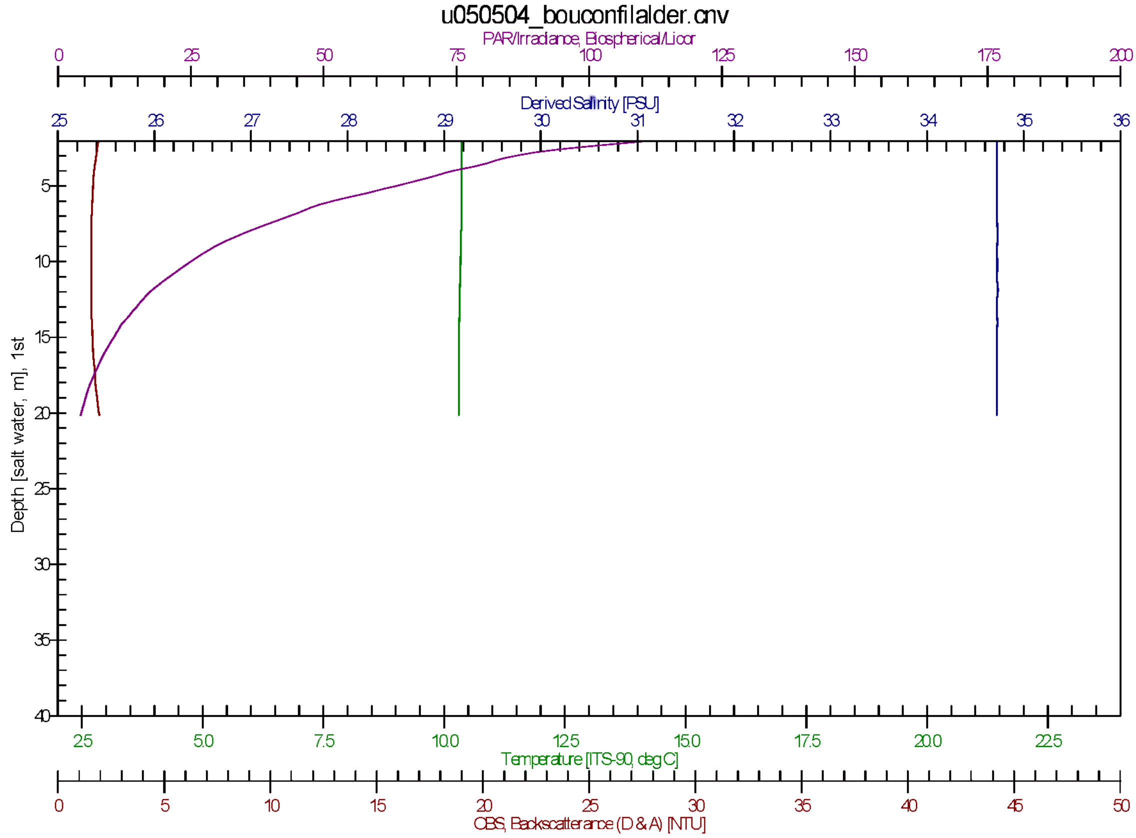


Figure A4-21

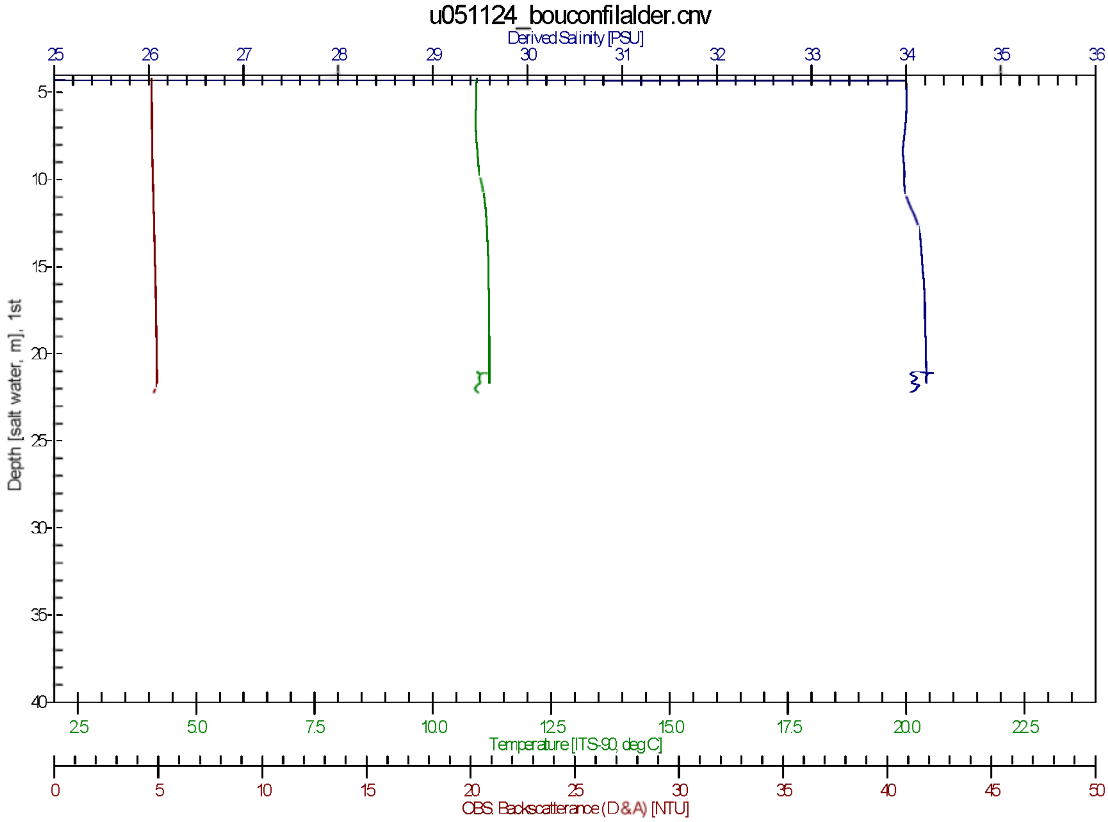


Figure A4-22

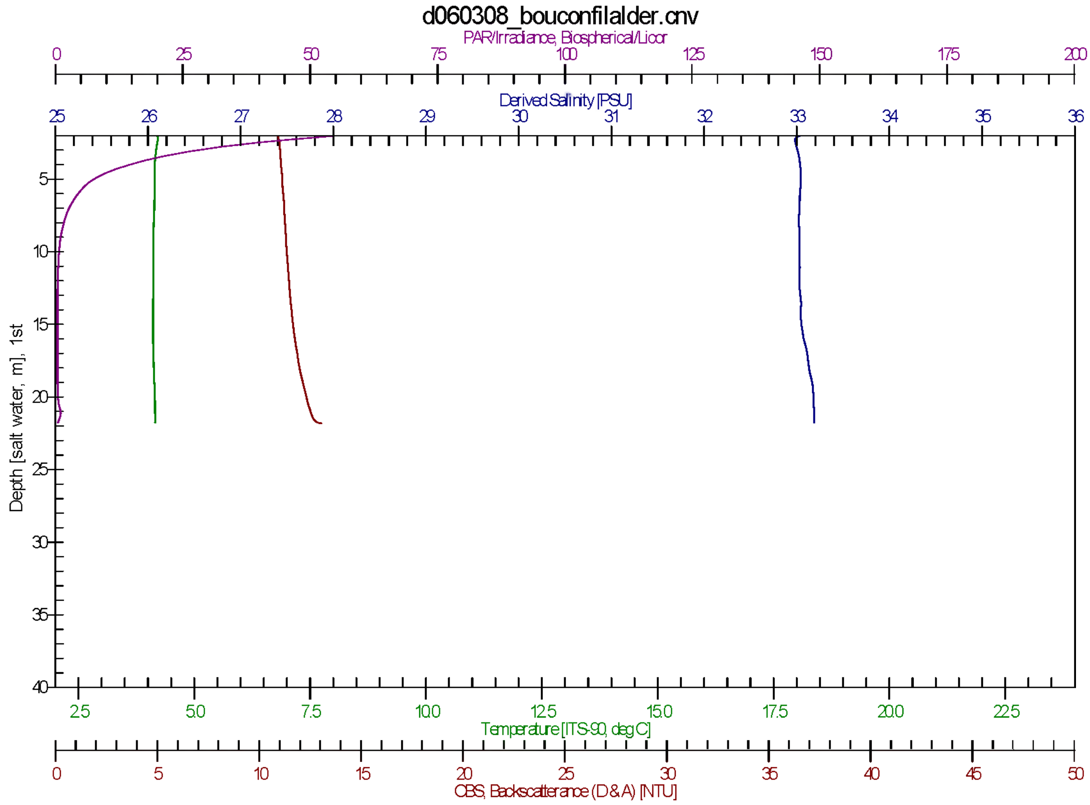


Figure A4-23

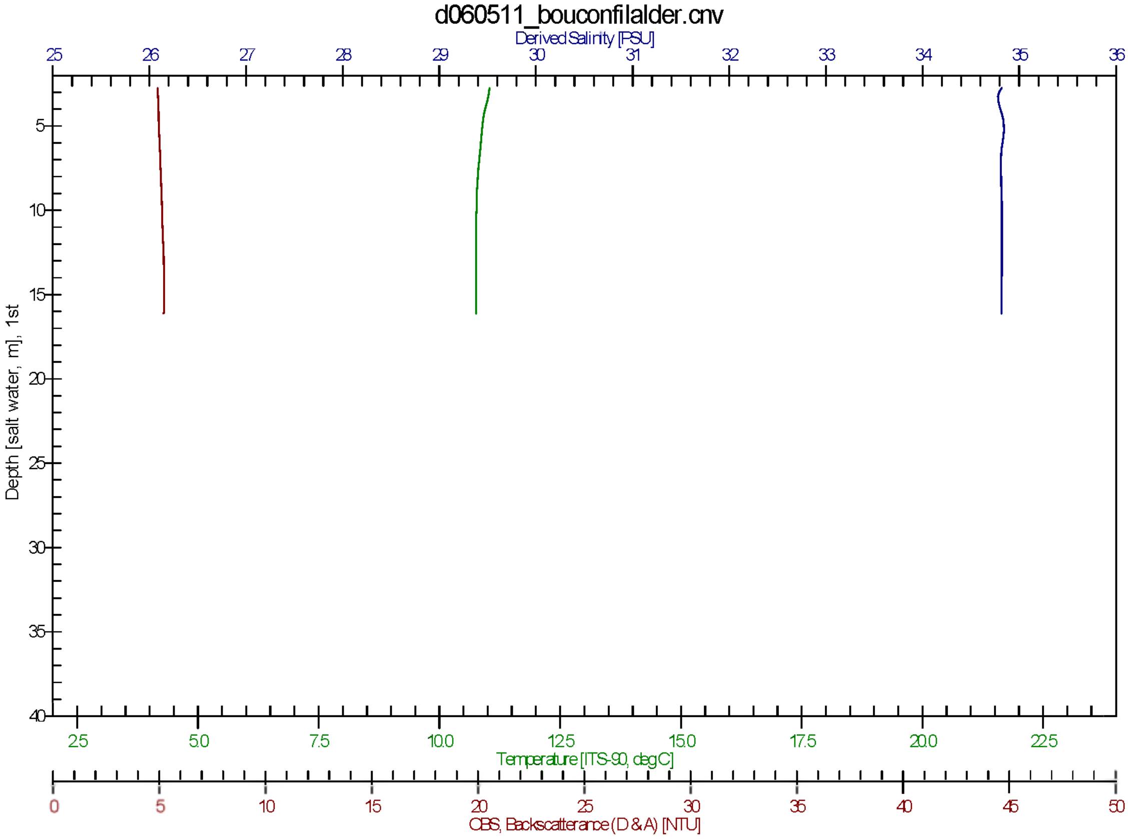

d060511_bouconfilalder.cnv
Derived Salinity [PSU]
25 26 27 28 29 30 31 32 33 34 35 36
Depth [salt water, m], 1st
5 10 15 20 25 30 35 40
2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5
Temperature [ITS-90, deg C]
0 5 10 15 20 25 30 35 40 45 50
OBS, Backscatterance (D & A) [NTU]

Figure A4-24

Kilmore
(WGS84 N 51°23',730 E 002°29',790)

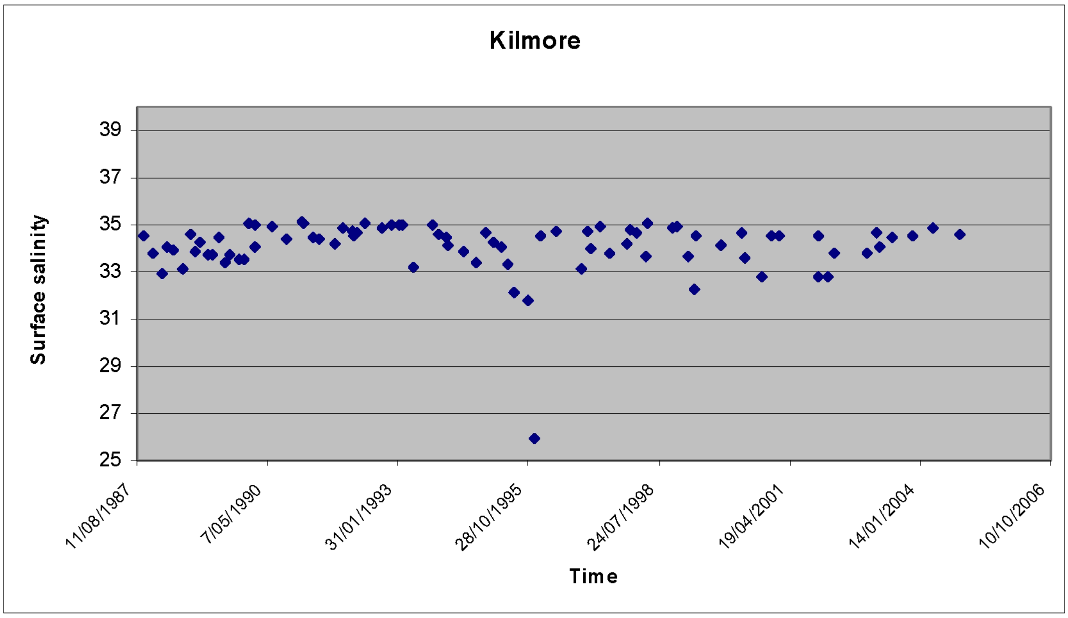


Figure A4-25: Surface Salinity. Station Kilmore from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

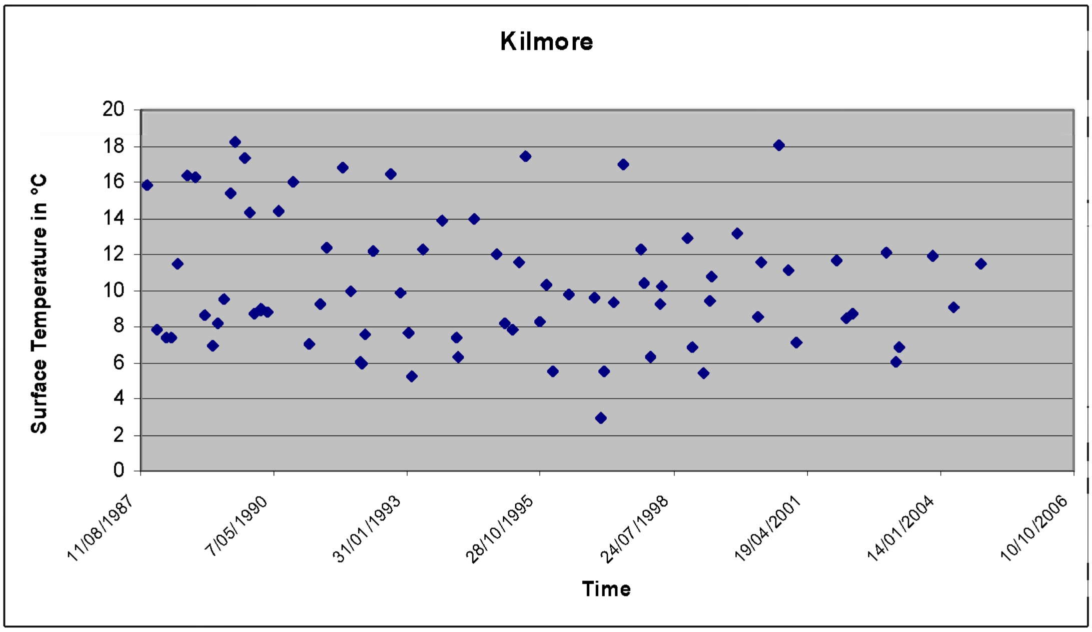


Figure A4-26: Surface Temperature. Station Kilmore from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

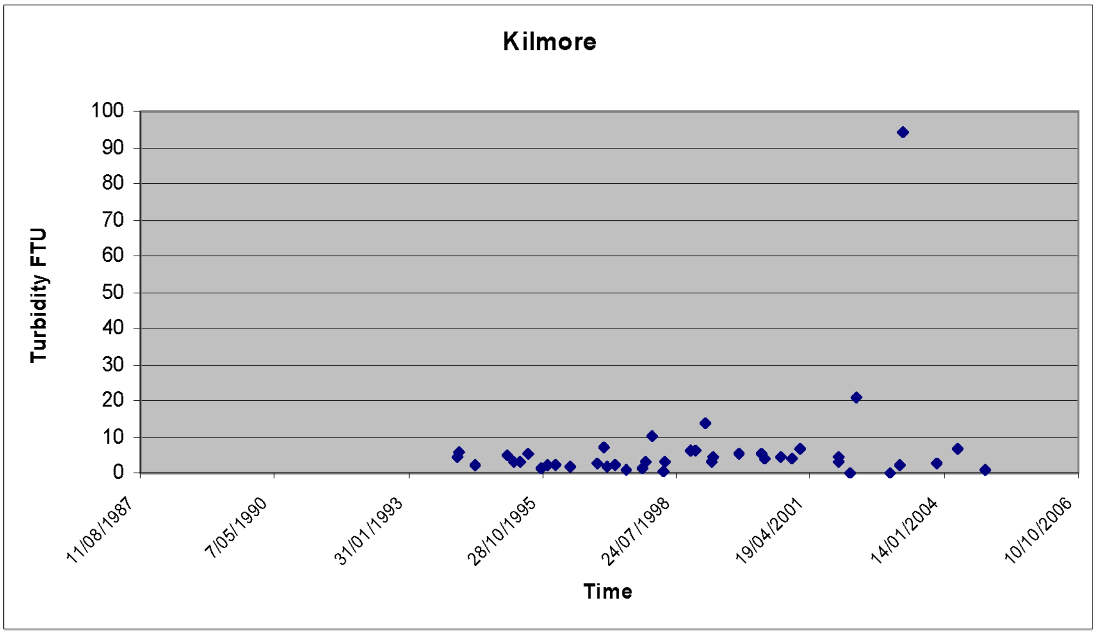


Figure A4-27: Turbidity . Station Kilmore from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

Kilmore	Salinity	Temp.	Turbidity
mean	34.07	10.41	6.68
std	1.15	3.54	14.64
min	25.91	2.91	0.49
max	35.11	18.20	94.07
mediane	34.41	9.69	3.54
number	86		

Table A4-7: Elementary statistics for station Kilmore from BMDC (Mumm) and IMERS (Vliz) data

KLM 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	5.02	7.48	6.27	32.75	34.88	34.15	0.71	
2	1.99	9.18	6.97	32.97	34.88	34.00	1.90	0.06
3	3.72	8.80	6.98	31.65	35.00	33.44	1.56	0.78
4	6.95	10.34	8.84	31.96	35.24	33.89	0.97	1.09
5	9.54	13.55	11.48	32.07	34.85	34.10	0.77	0.85
6	12.51	17.56	14.31	33.68	34.97	34.42	0.81	0.20
7	15.39	18.58	16.56	32.71	34.73	34.17	0.78	0.50
8	17.62	21.40	19.27	32.94	34.99	34.24	0.90	0.42
9	15.79	20.13	17.70	30.55	35.03	34.29	0.88	0.43
10	6.81	17.51	15.59	32.51	34.96	34.25	1.14	0.47
11	8.00	13.71	11.69	31.45	35.13	34.18	1.22	0.88
12	6.23	12.62	9.55	30.69	34.95	34.25	1.51	0.31

Table A4-8: Kilmore: monthly mean temperature and salinity from R/V Belgica underway data (1993-2006) Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

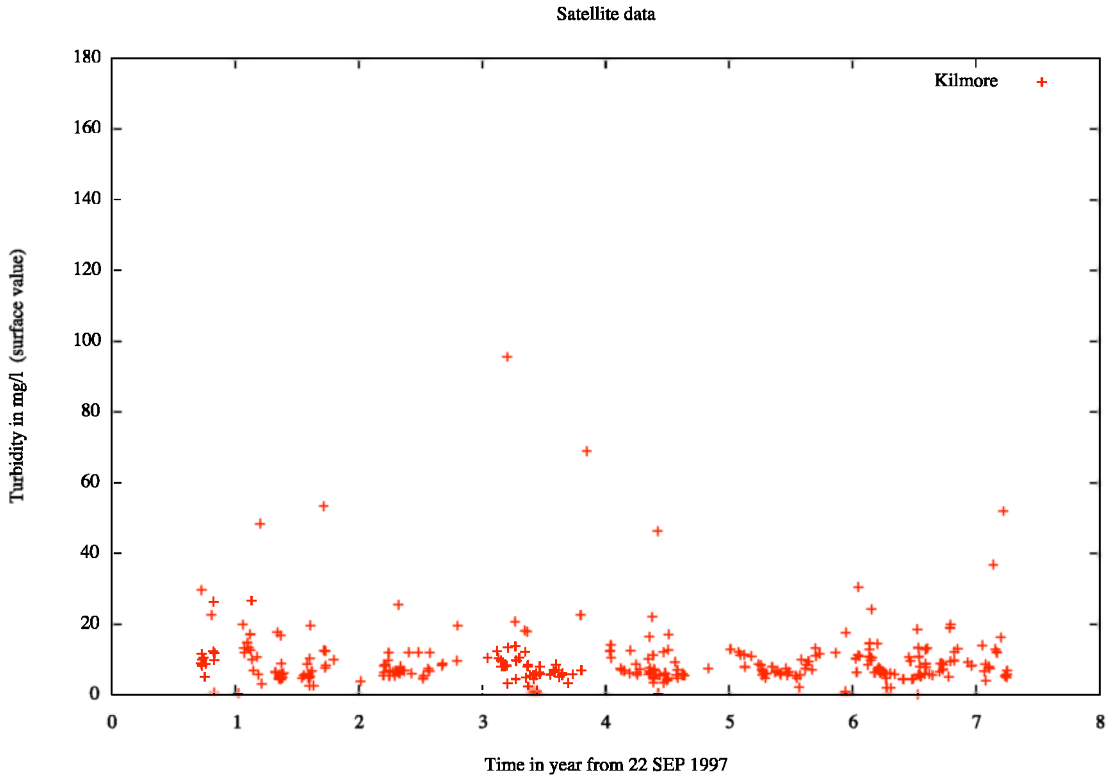


Figure A4-28: Total suspended matter in mg/l for station Kilmore.
Data derived from SeaWifs 670 nm band

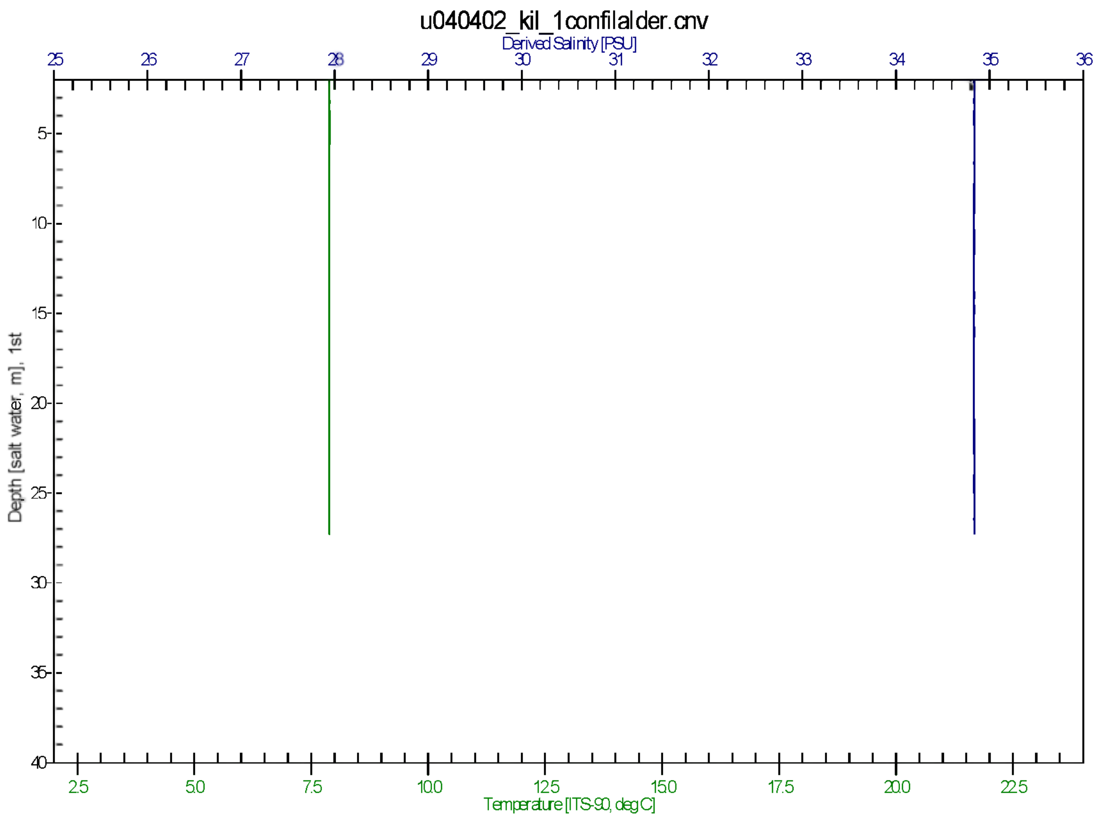
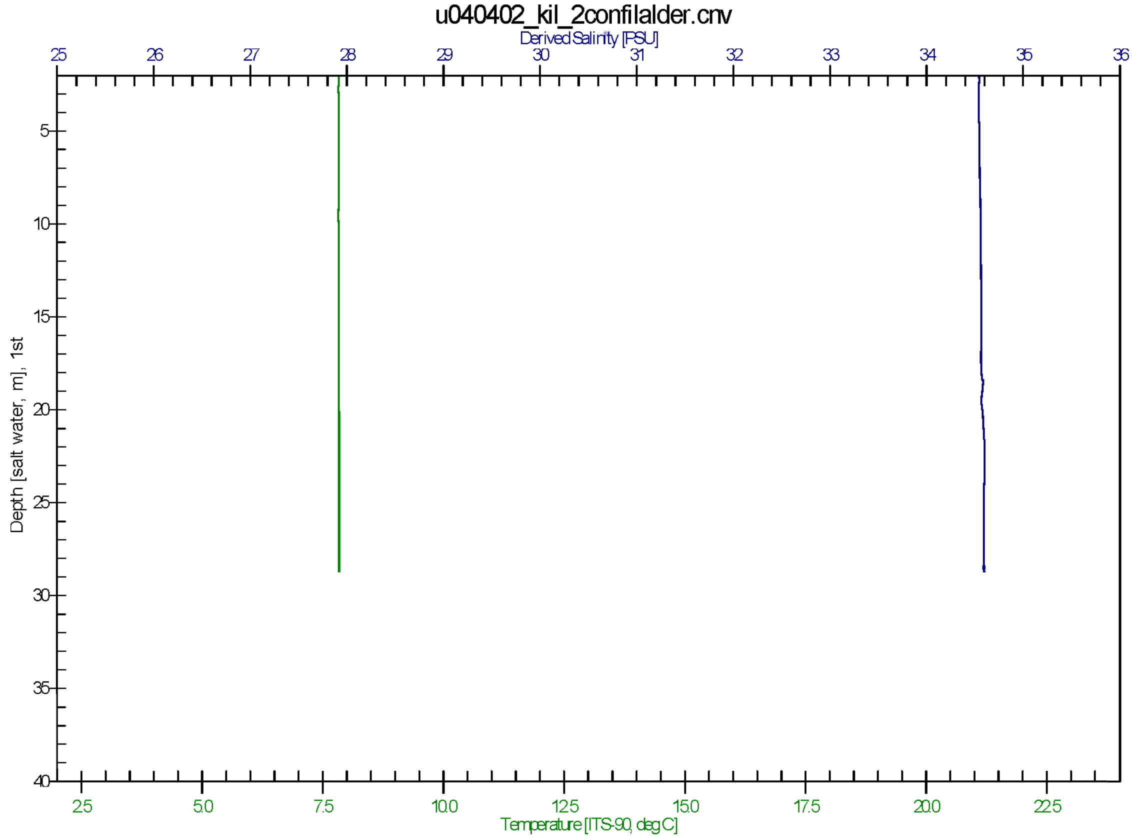
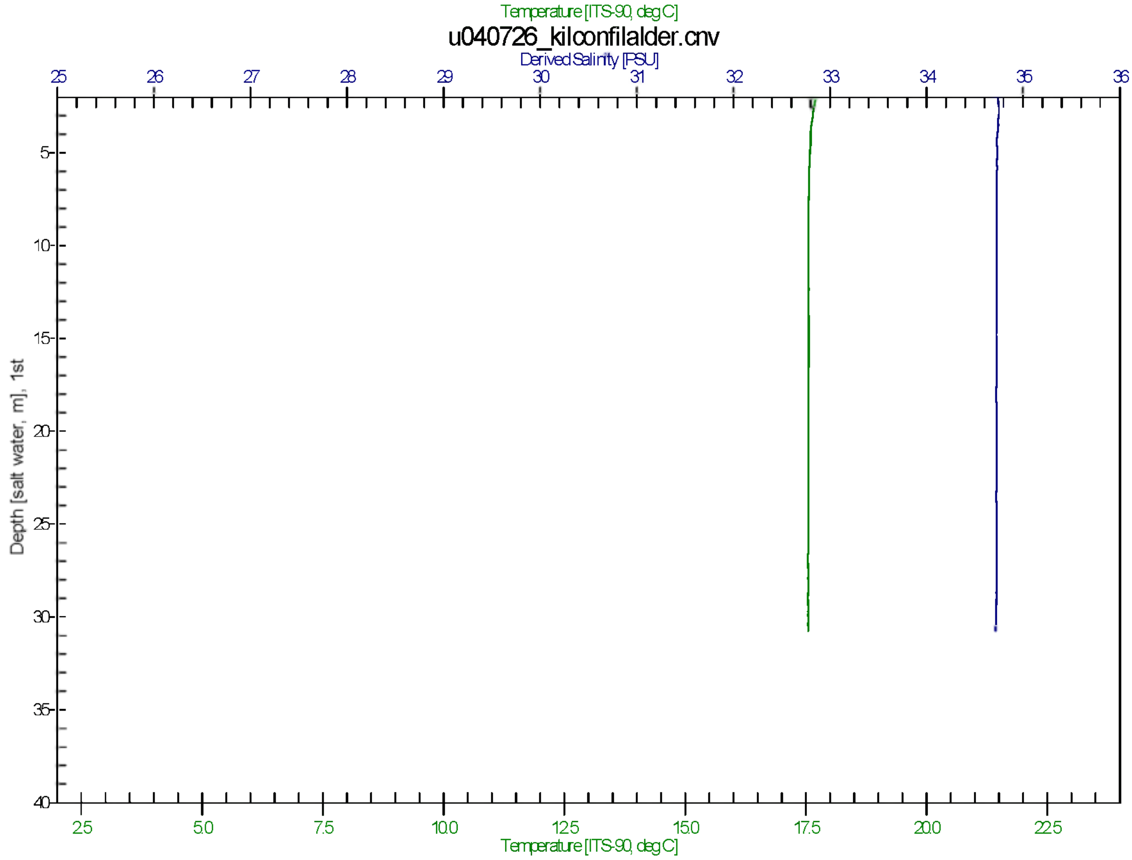


Figure A4-29





Figures A4-30, 31

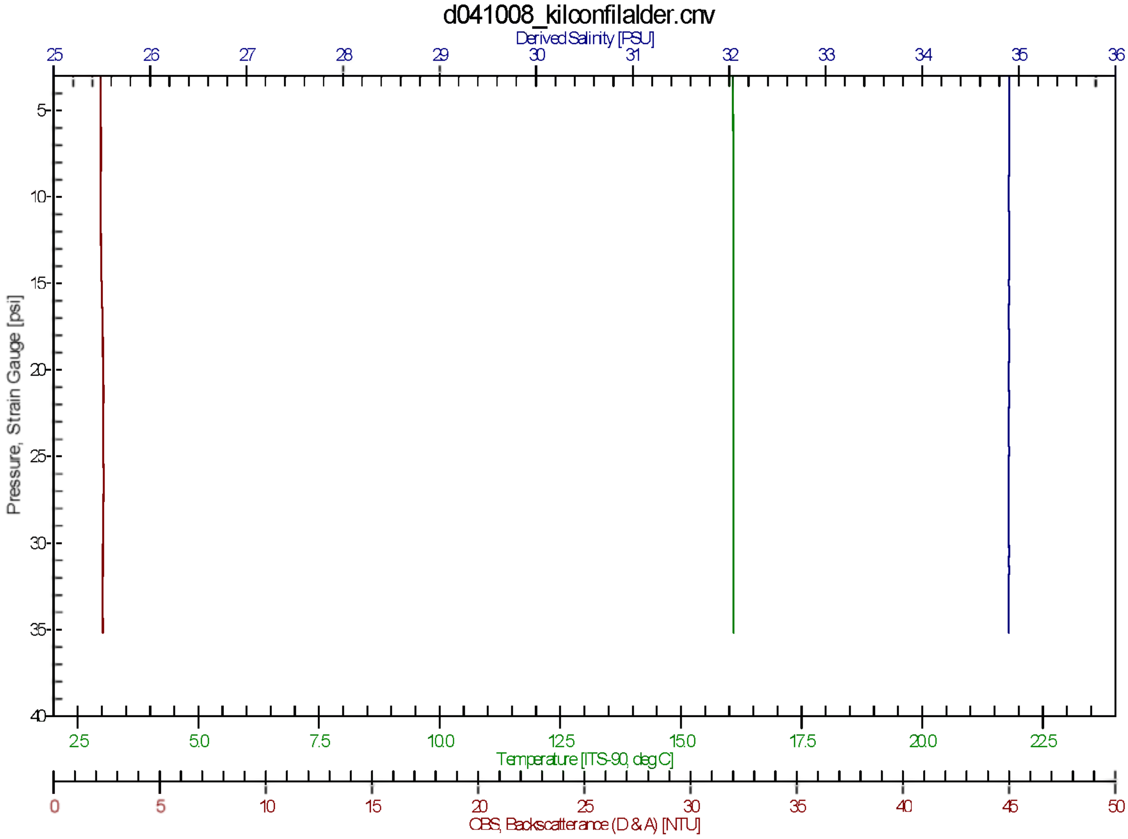


Figure A4-32

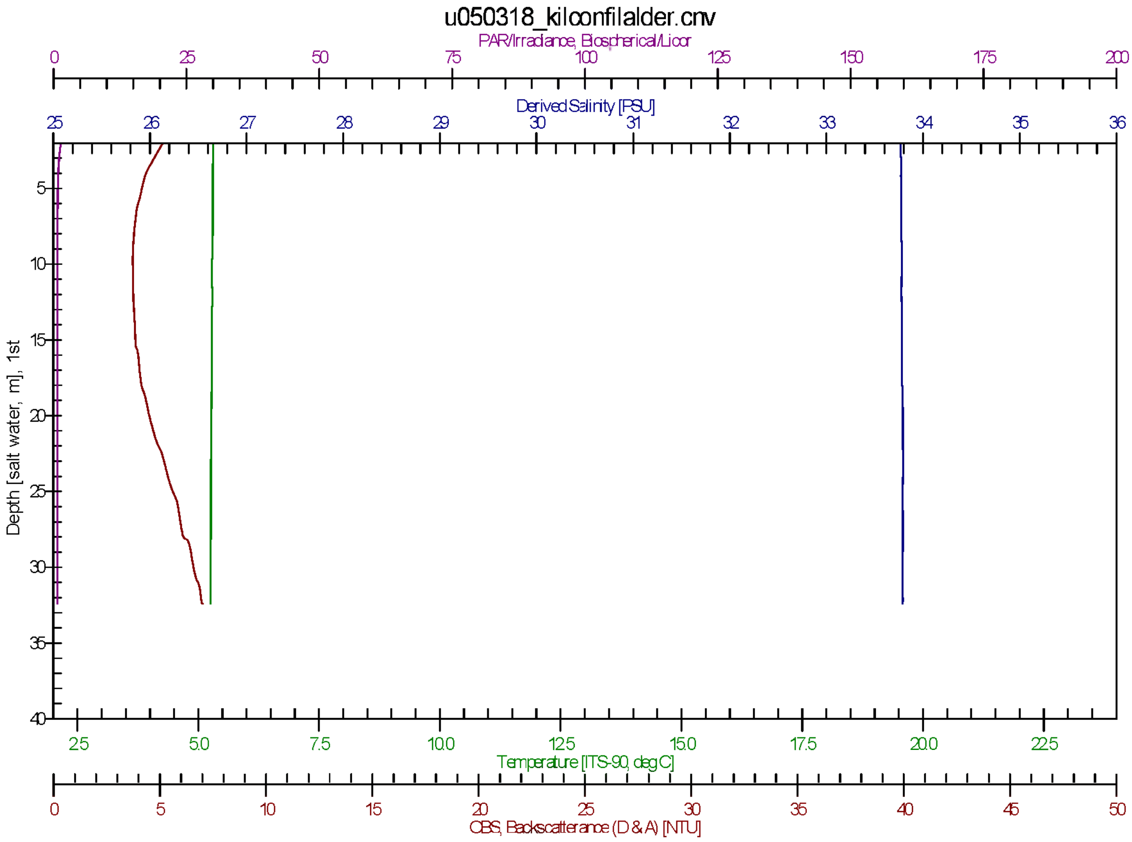


Figure A4-33

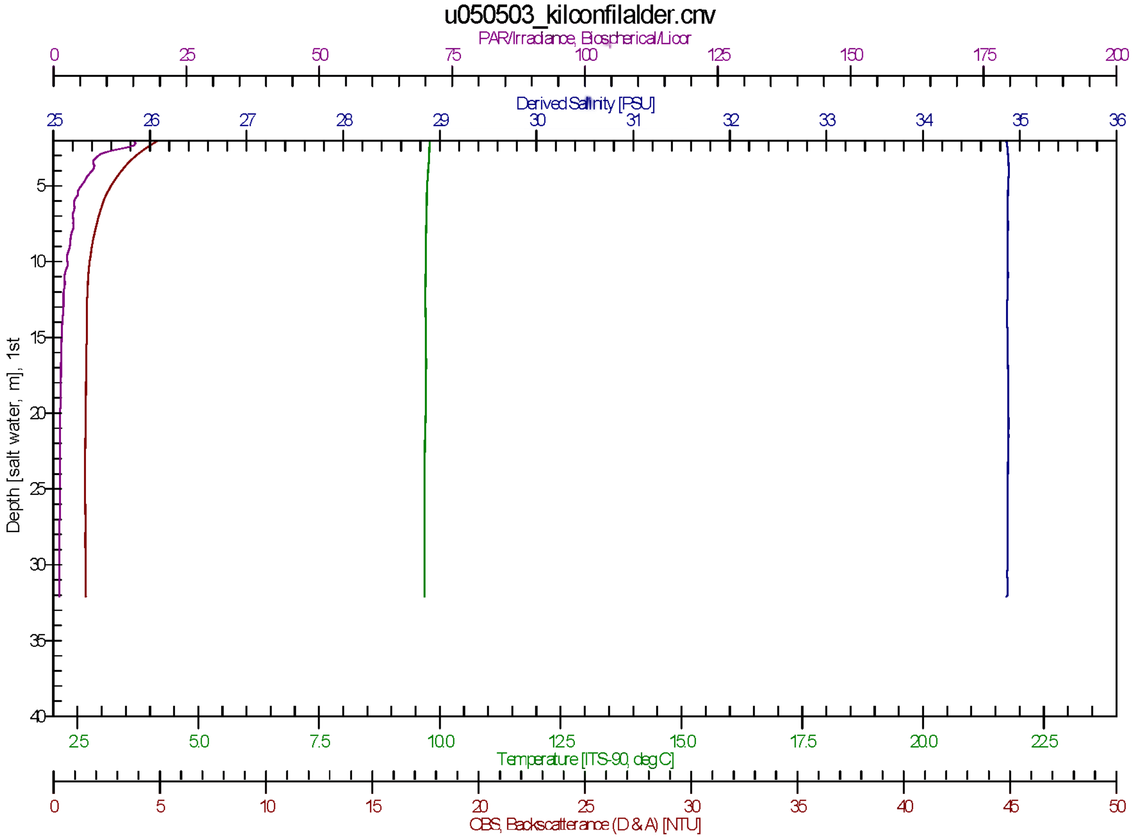


Figure A4-34

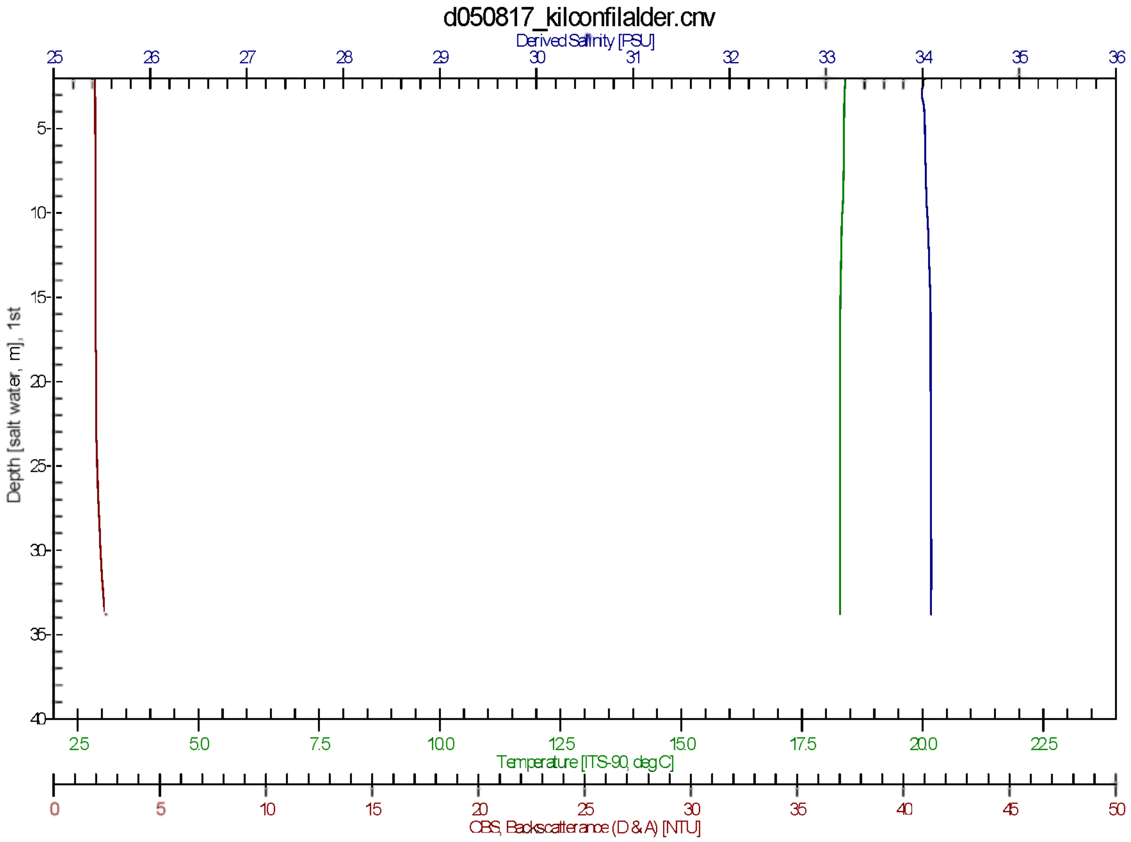


Figure A4-35

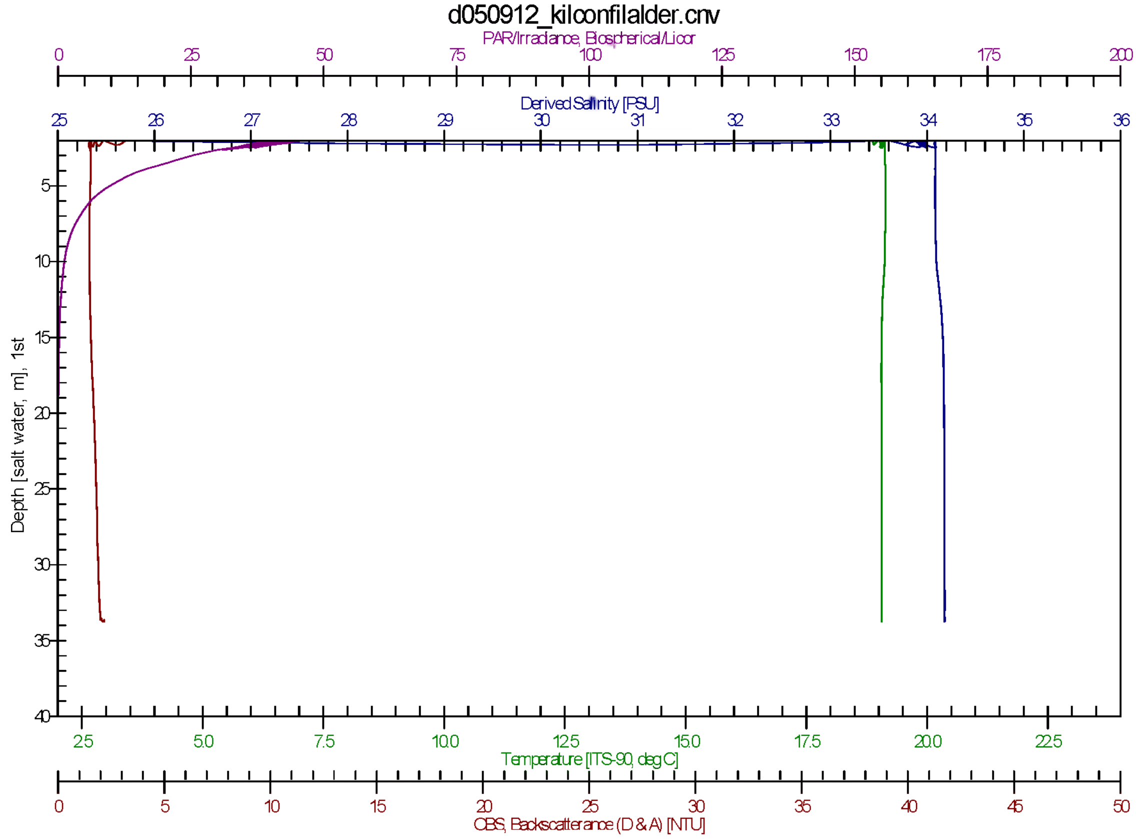


Figure A4-36

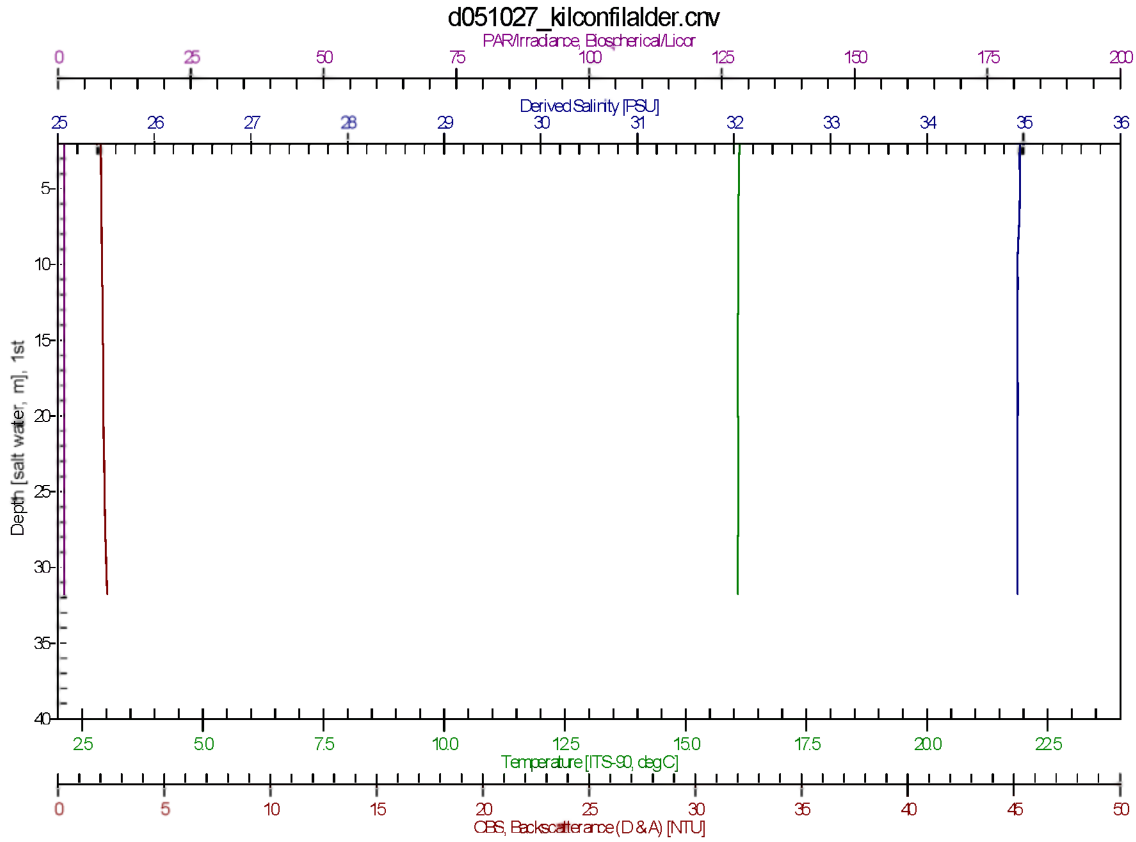


Figure A4-37

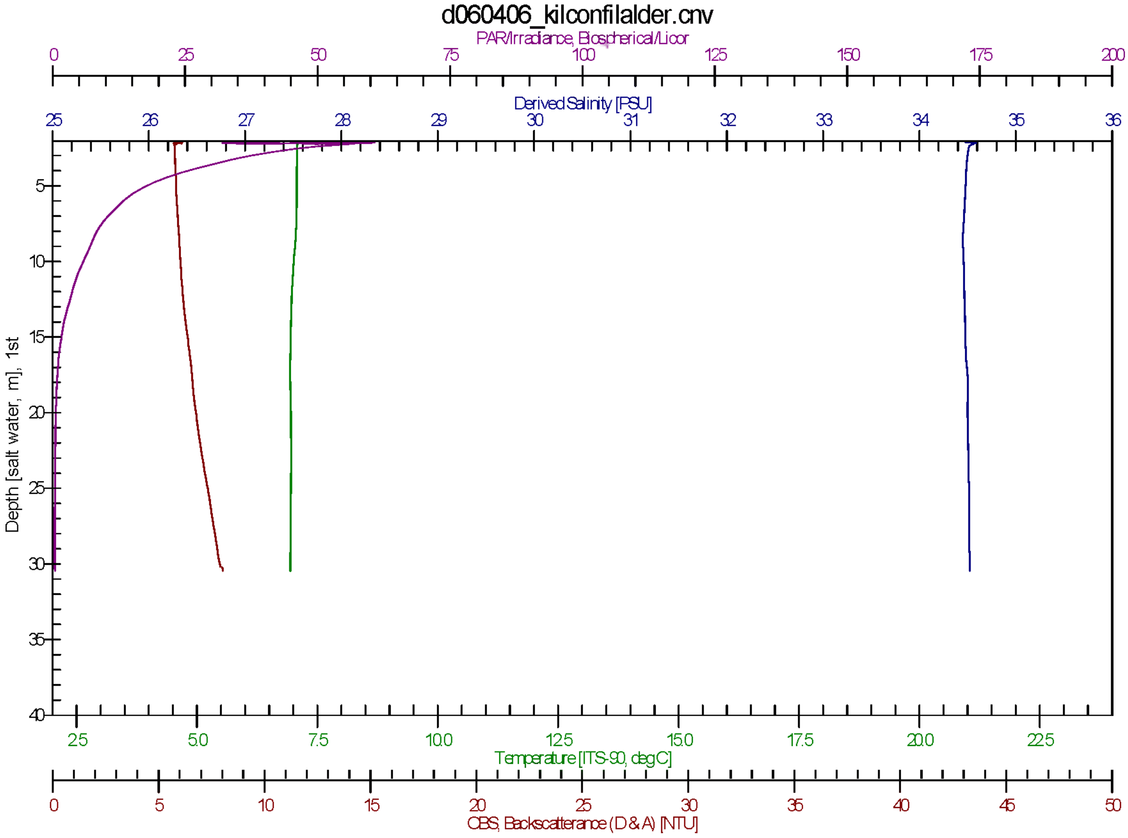


Figure A4-38

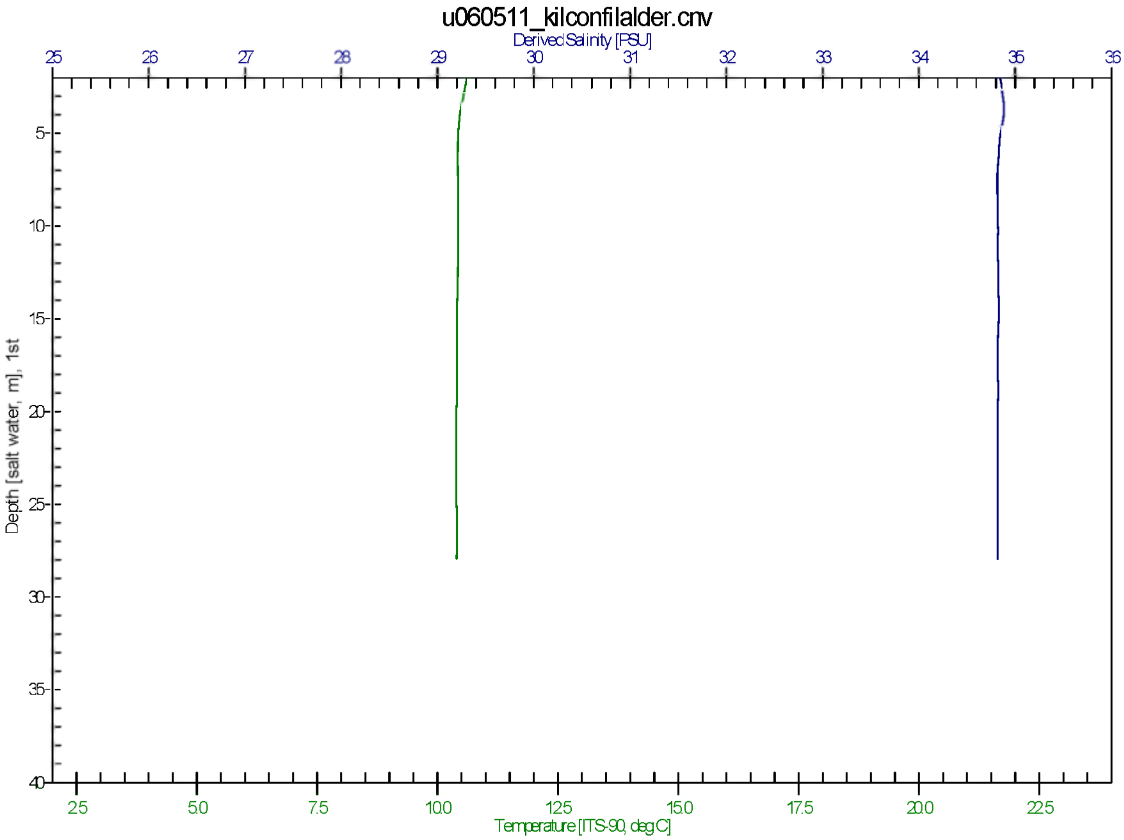


Figure A4-39

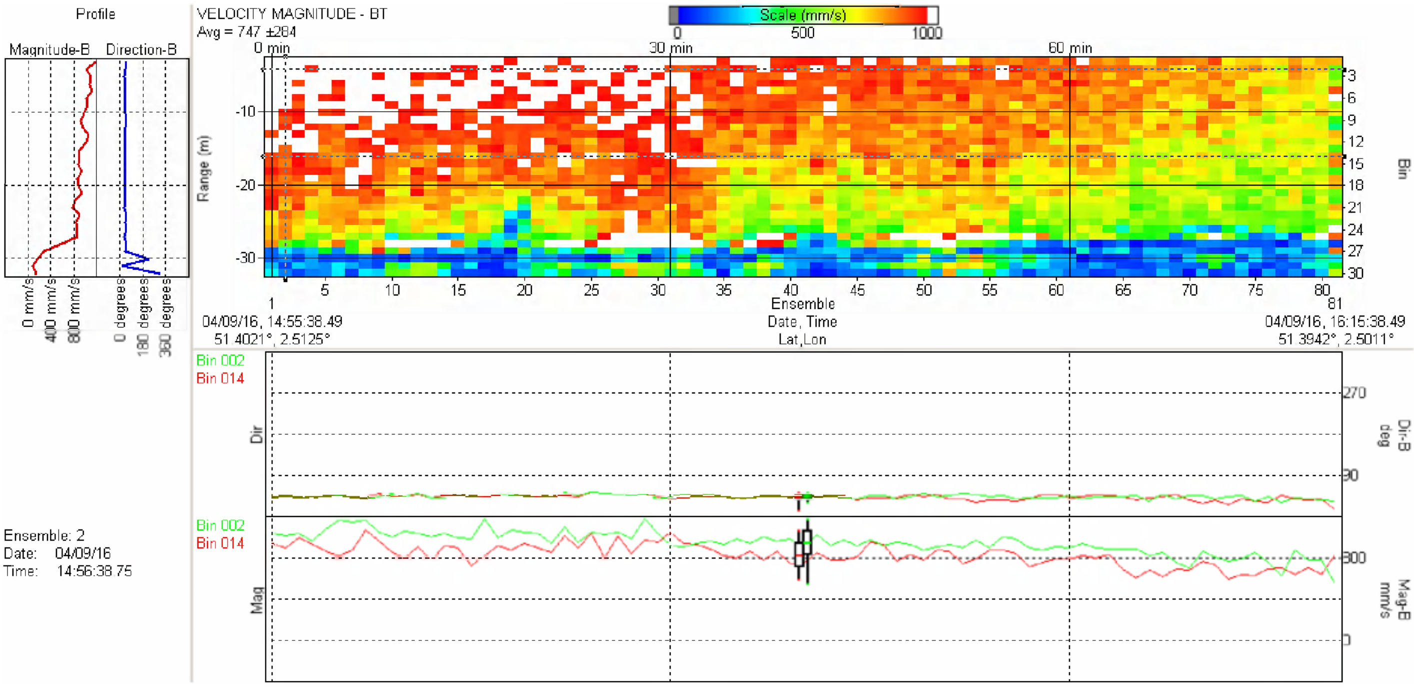


Figure A4-40: Kilmore wreck Date: 16 September 2004 HW at Oostende 02:53 and 15:06 (UT+2)

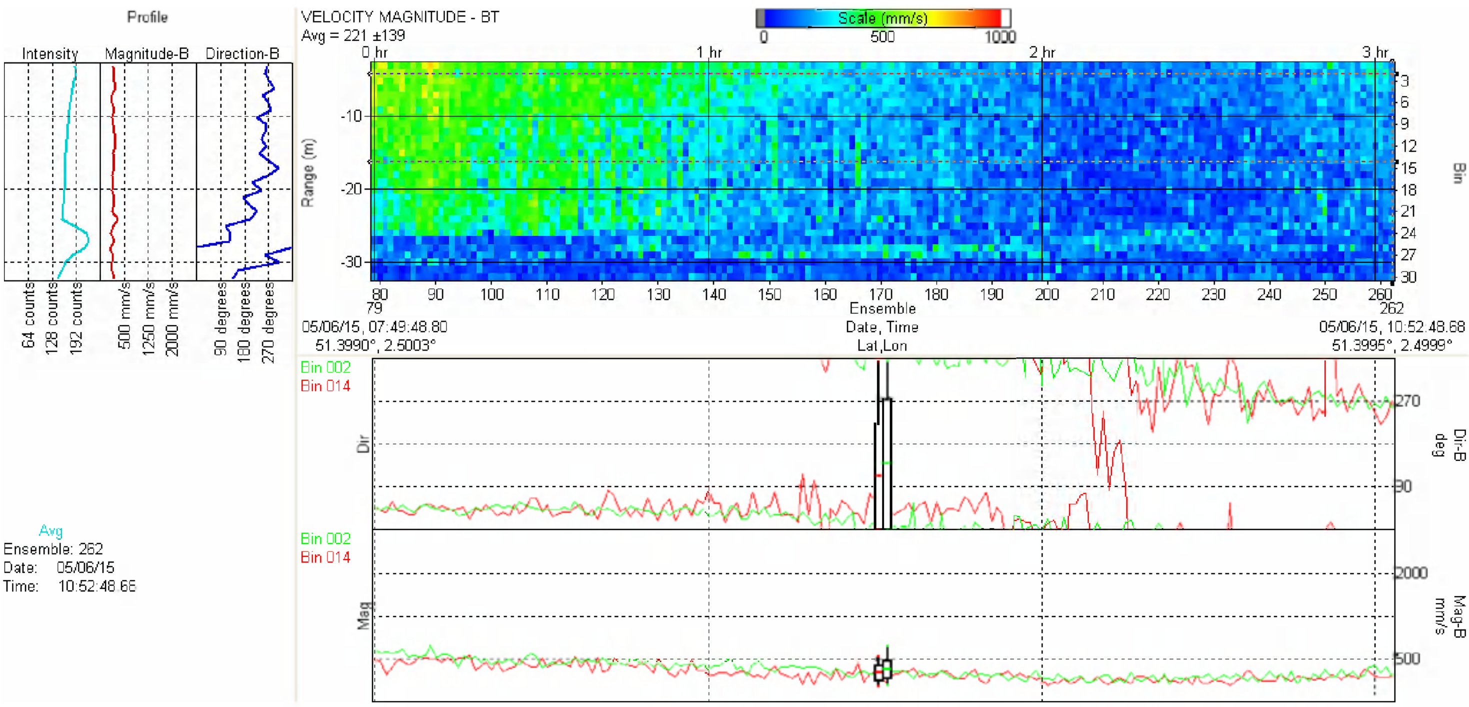


Figure A4-41: Kilmore wreck. Date 15 June 2005 HW at Oostende 07:53 and 20:22 (UT+2)

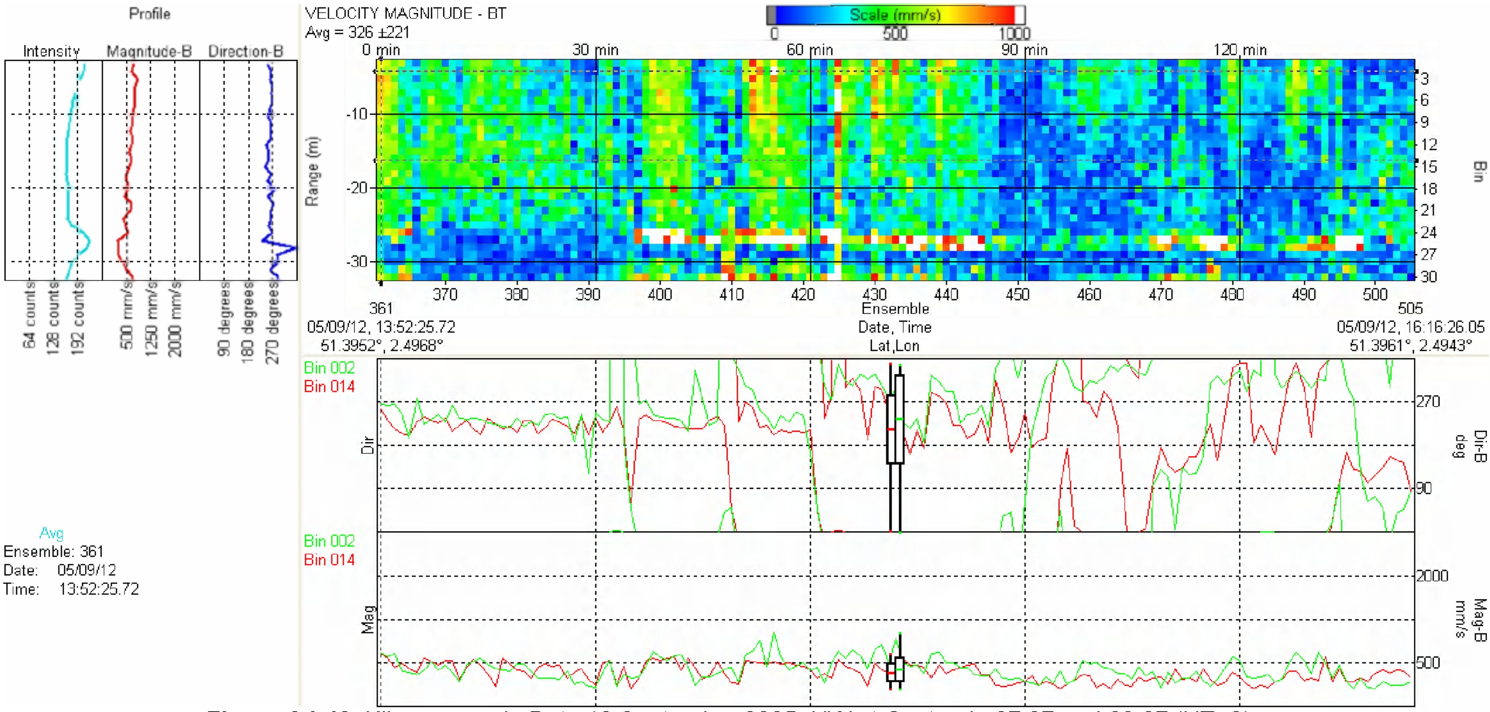


Figure A4-42: Kilmore wreck .Date 12 September 2005. HW at Oostende 07:27 and 20:07 (UT+2)

Sperrbrecher 142 142
also named WESTEBROEK (WGS84 N 51°16,65 E 002°49,78)

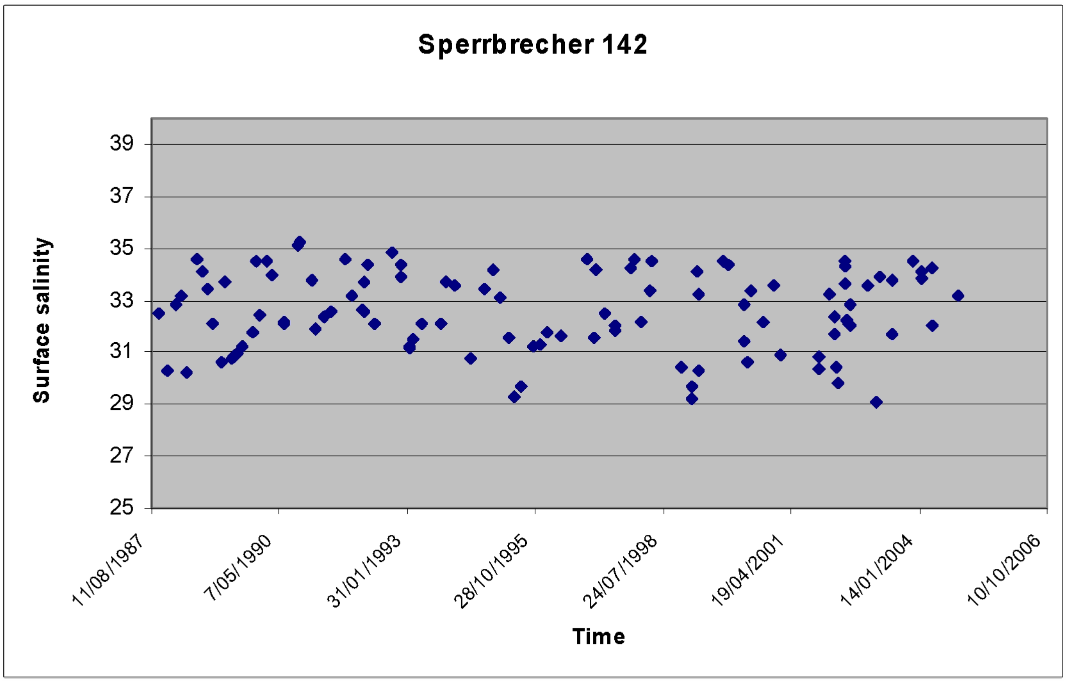


Figure A4-43: Surface Salinity. Station Sperrbrecher 142 142 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

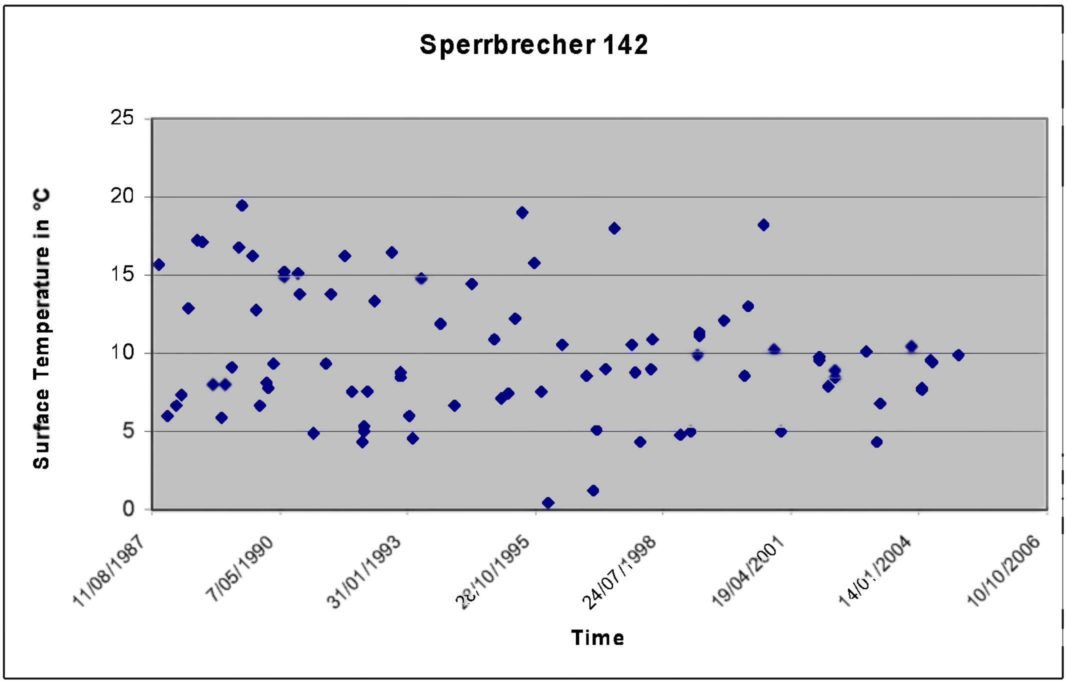


Figure A4-44: Surface Temperature. Station Sperrbrecher 142 142 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

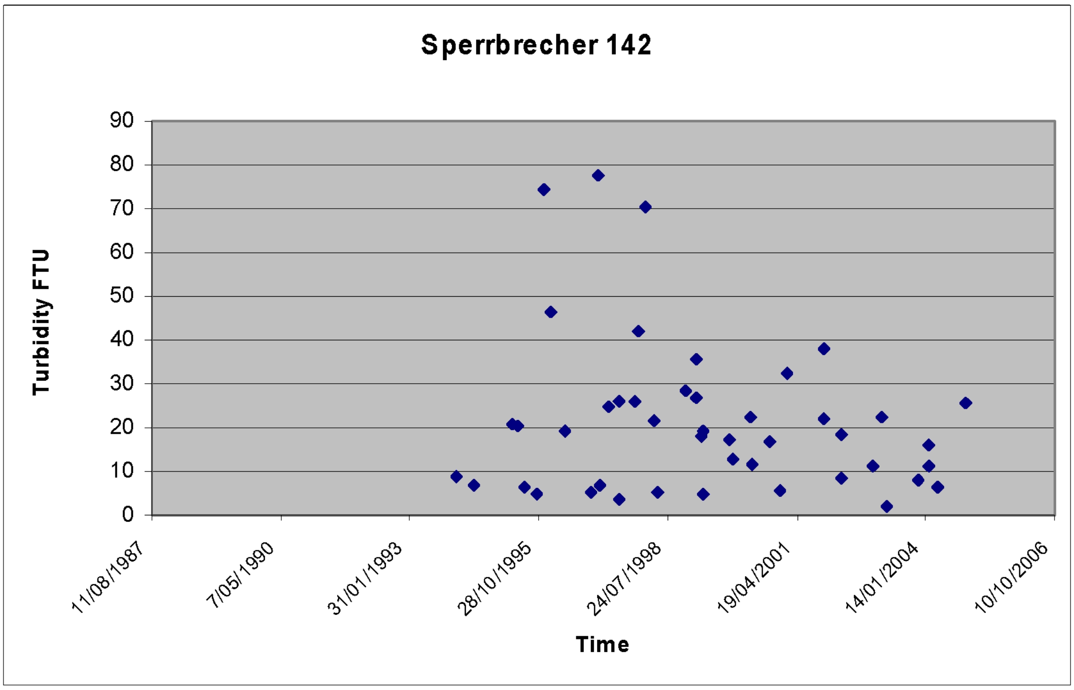


Figure A4-45: Turbidity . Station Sperrbrecher 142 142 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

Speerbrecher	Salinity	Temp.	Tubidity
mean	32.55	10.01	20.99
std	1.52	4.17	17.81
min	29.07	0.47	1.83
max	35.23	19.45	77.66
mediane	32.50	9.35	18.32
number	113		

Table A4-9: Elementary statistics for station Sperrbrecher 142 142 from BMDC (Mumm) and IMERS (Vliz) data

WES 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	-0.01	7.66	4.31	29.34	33.44	31.61	2.44	1.99
2	1.07	11.13	6.19	29.73	33.76	32.19	1.70	2.21
3	2.94	9.35	7.37	27.97	34.43	32.17	0.53	1.23
4	7.30	10.96	8.84	29.06	34.10	31.58	1.00	0.73
5	9.18	16.40	12.73	28.56	34.35	32.46	1.41	1.29
6	13.64	18.37	15.59	30.58	34.49	33.21	0.32	1.09
7	15.70	19.85	17.70	28.48	34.86	33.11	1.49	1.25
8	16.94	22.53	20.11	29.43	34.90	32.55	0.46	0.49
9	14.10	19.92	17.07	27.62	34.50	32.79	0.56	1.11
10	9.77	17.11	14.68	27.72	34.65	33.71	0.58	0.78
11	6.05	15.12	10.10	29.58	34.86	33.21	1.29	1.08
12	4.18	11.93	7.67	28.45	34.55	32.57	1.35	1.65

Table A4-10: Sperrbrecher 142 142: Monthly mean temperature and salinity from R/V Belgica underway data (1993-2006) Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

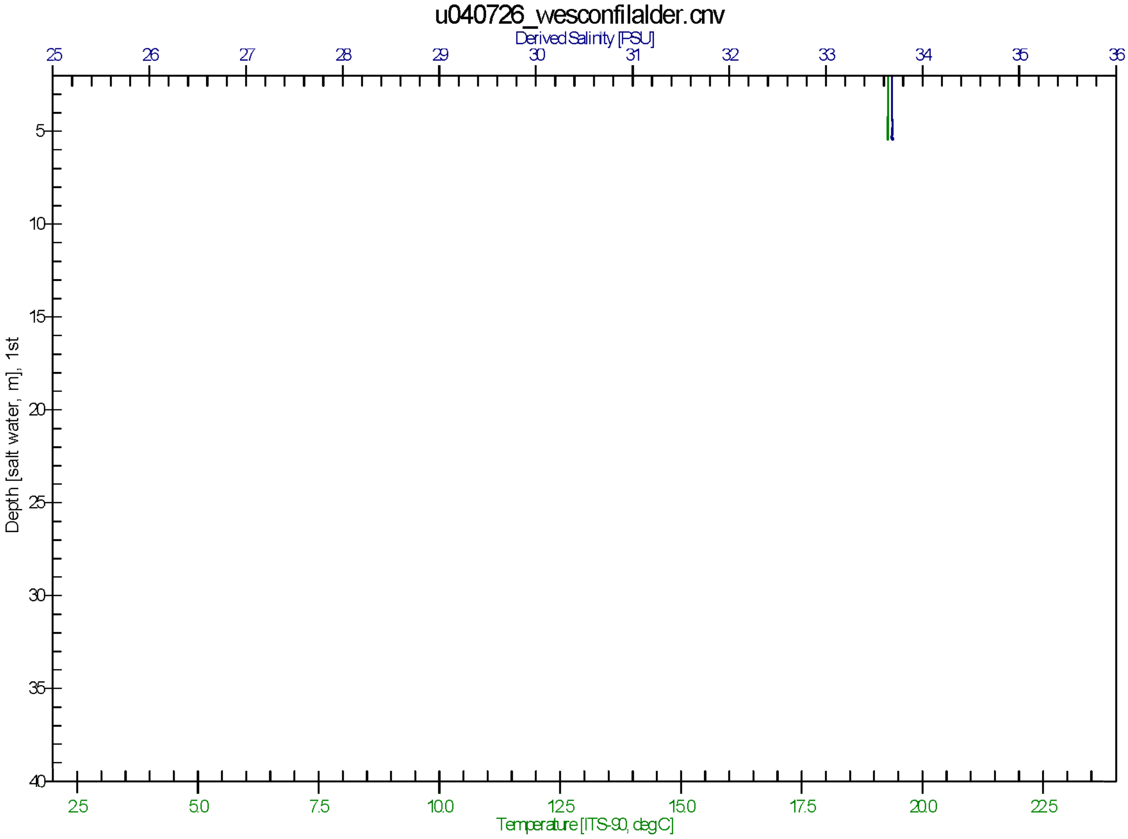


Figure A4-46

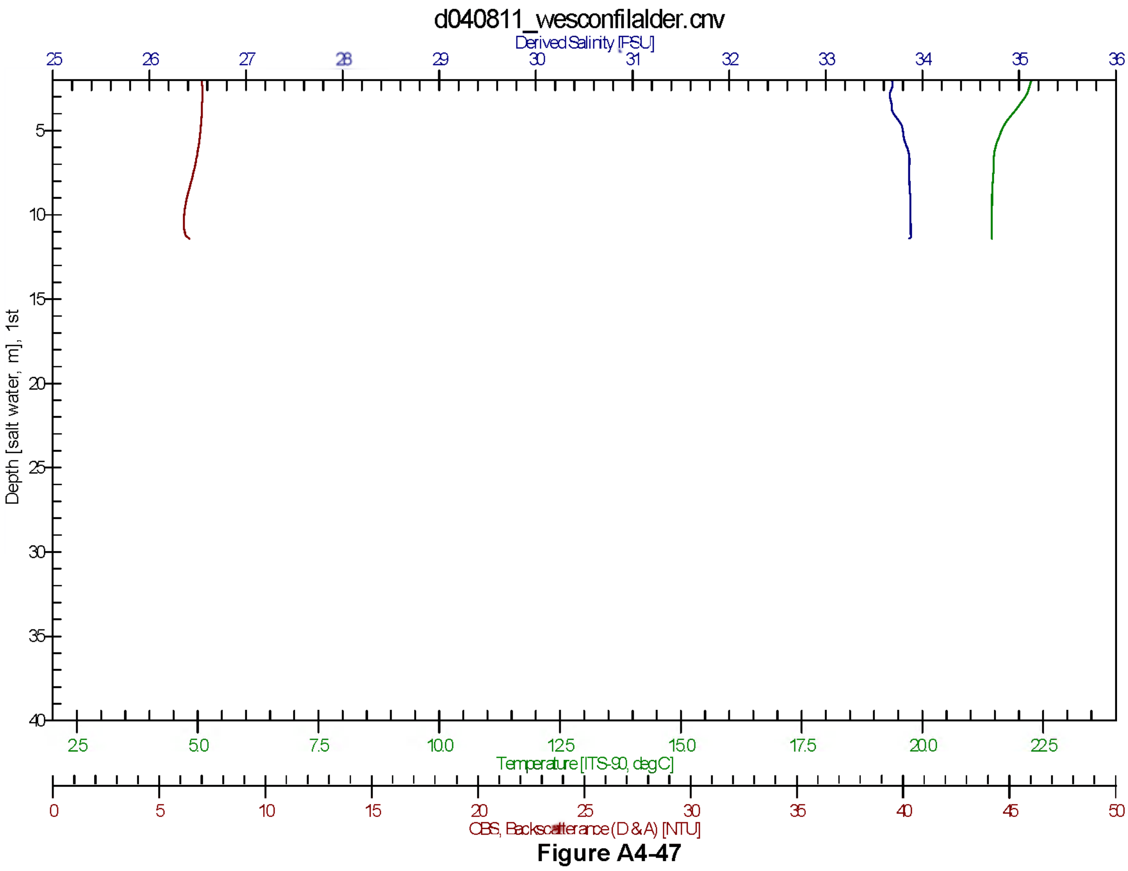
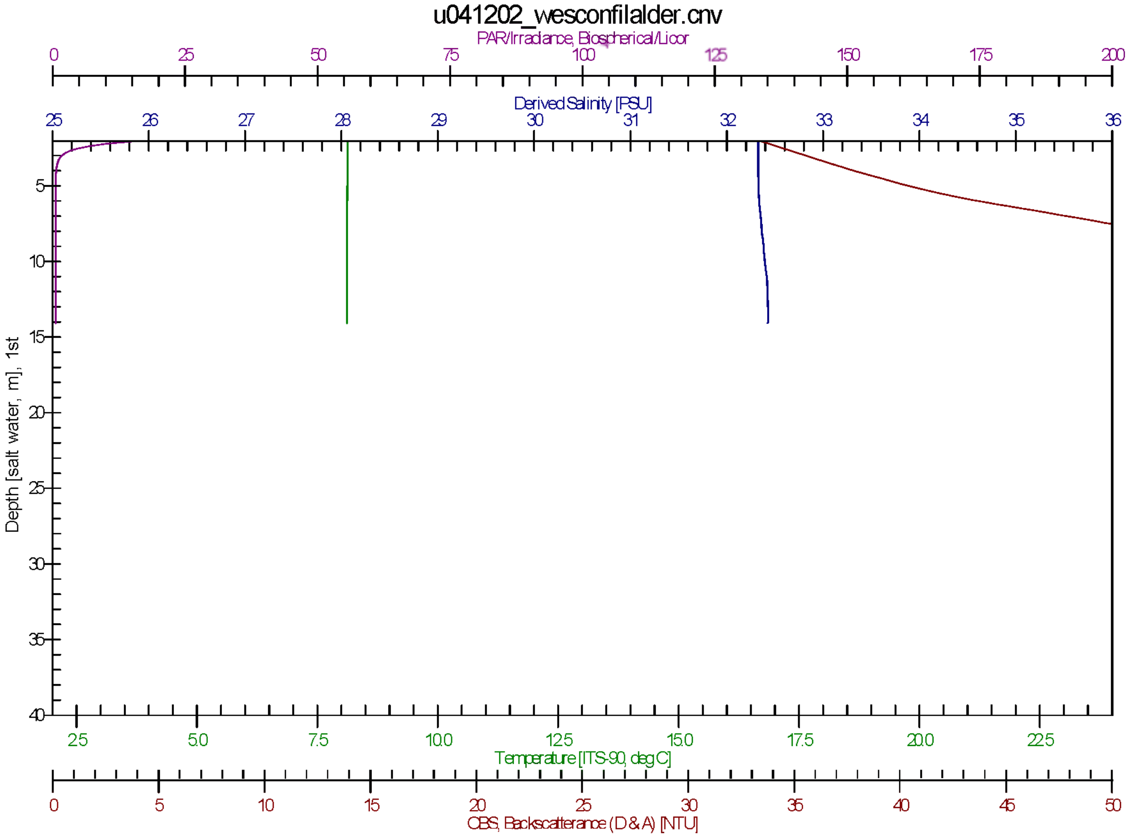


Figure A4-47



FigureA4-48

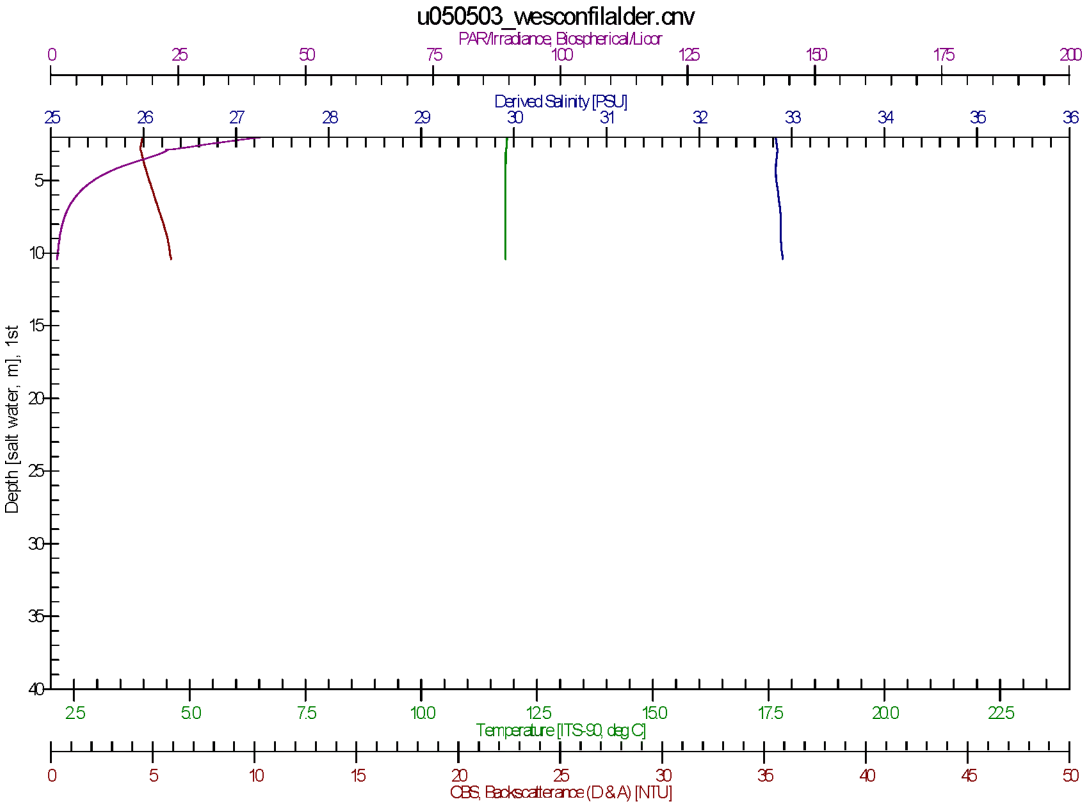


Figure A4-49

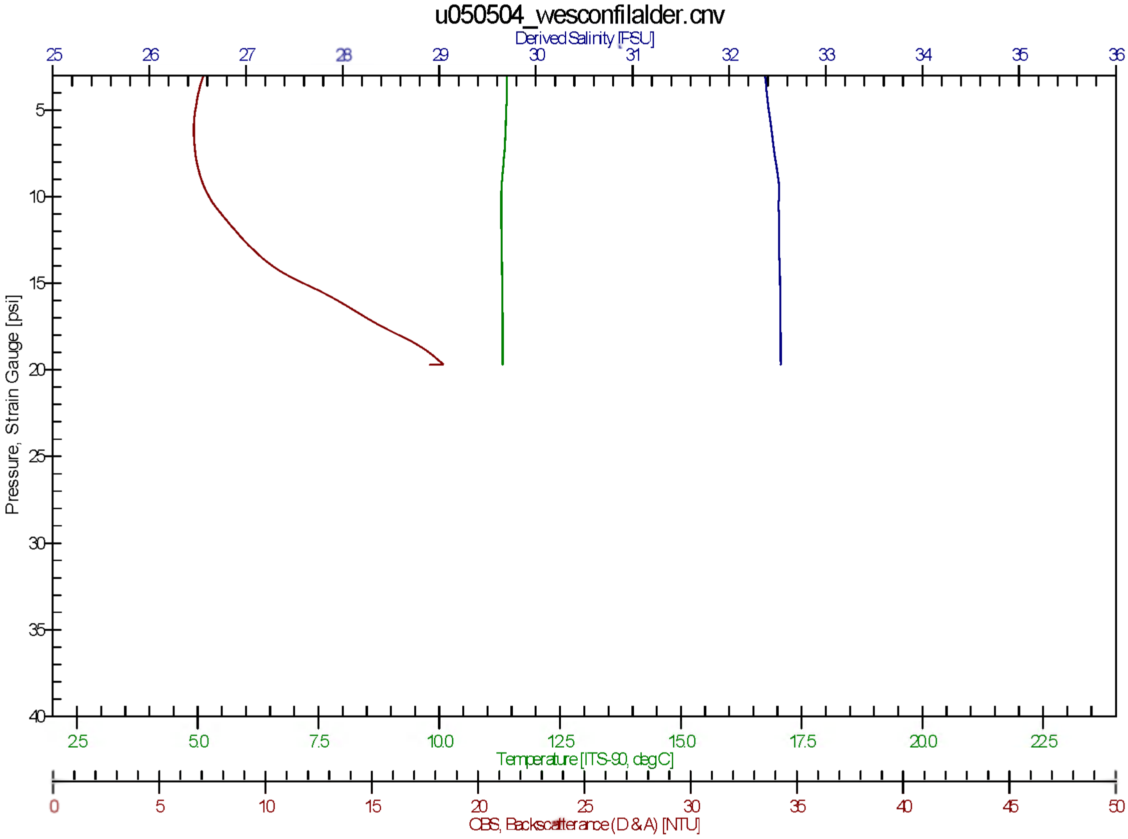

u050504_wesconfilalder.cnv
Derived Salinity [PSU]
25 26 27 28 29 30 31 32 33 34 35 36
Pressure, Strain Gauge [psi]
5 10 15 20 25 30 35 40
2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5
Temperature [ITS-90, deg C]
0 5 10 15 20 25 30 35 40 45 50
OBS, Backscatterance (D & A) [NTU]

Figure A4-50

LST420
(WGS84 N 51°15,460 E 002°40,755)

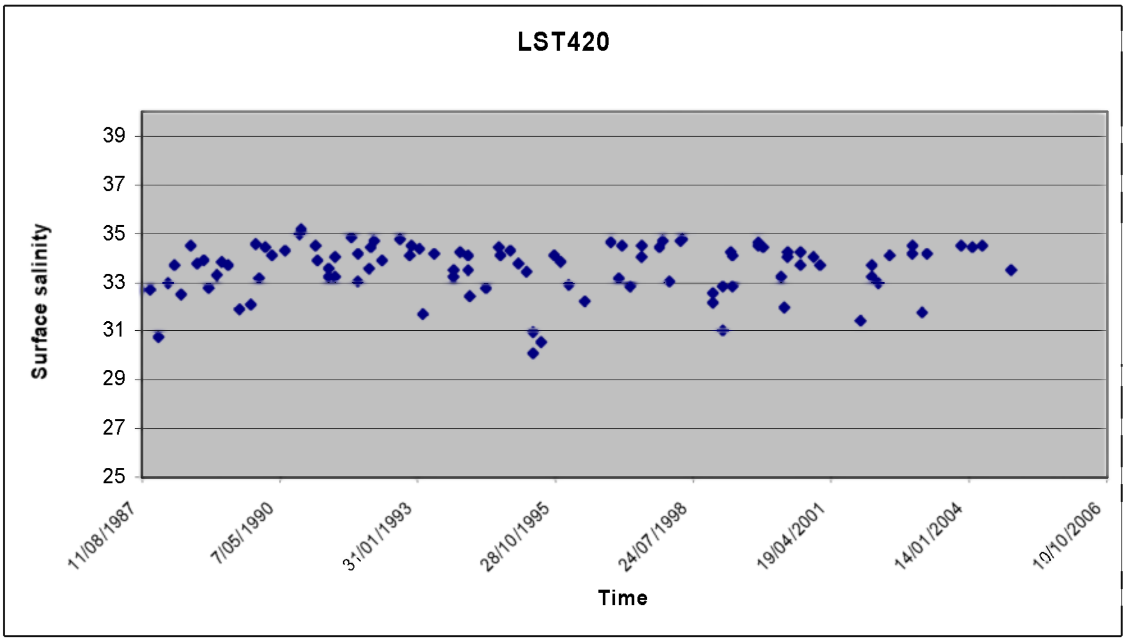


Figure A4-51: Surface Salinity. Station LST 420 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

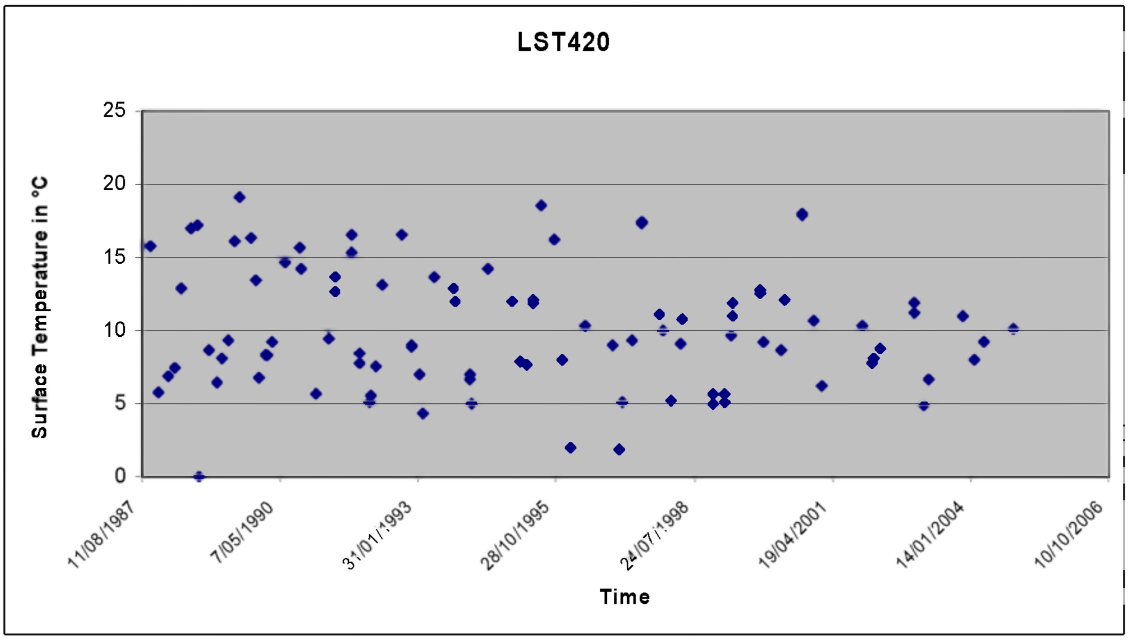


Figure A4-52: Surface Temperature. Station LST 420 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

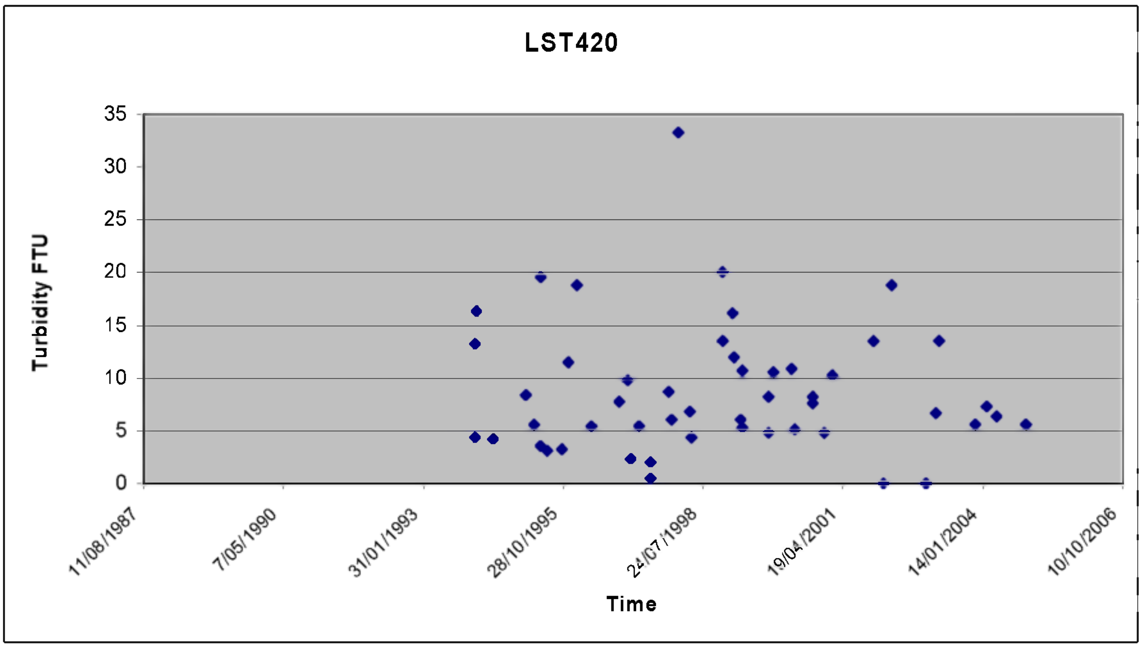


Figure A4-53: Turbidity . Station LST 420 from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

Lst 420	Salinity	Temp.	Turbidity
mean	33.55	10.34	9.09
std	1.06	3.94	6.05
min	30.06	1.84	0.49
max	35.21	19.15	33.33
mediane	33.84	9.53	7.52
number	107		

Table A4-11: Elementary statistics for station LST420 from BMDC (Mumm) and IMERS (Vliz) data

LST 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	0.38	6.06	3.65	29.35	33.37	31.57	2.26	
2	1.21	11.13	5.70	30.12	33.64	32.29	2.34	1.05
3	2.58	9.19	6.77	29.52	34.63	32.73	1.88	0.97
4	7.24	11.56	9.21	29.65	35.02	32.70	0.80	1.55
5	9.23	15.43	12.14	29.90	34.49	33.52	1.03	1.08
6	13.50	18.28	15.35	32.35	34.78	34.20	0.76	0.34
7	15.70	19.85	17.34	30.87	34.86	33.71	0.83	0.78
8	18.63	21.90	19.87	32.29	34.88	33.84	0.96	0.50
9	14.09	20.43	17.47	30.83	34.97	33.84	1.18	0.76
10	10.39	17.25	14.82	31.20	34.98	33.92	1.10	0.42
11	7.75	13.28	10.29	30.32	34.60	33.35	0.90	1.21
12	4.05	12.05	8.16	30.69	34.80	33.57	2.30	1.07

Table A4-12: LST420: monthly mean temperature and salinity from R/V Belgica underway data (1993-2006). Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

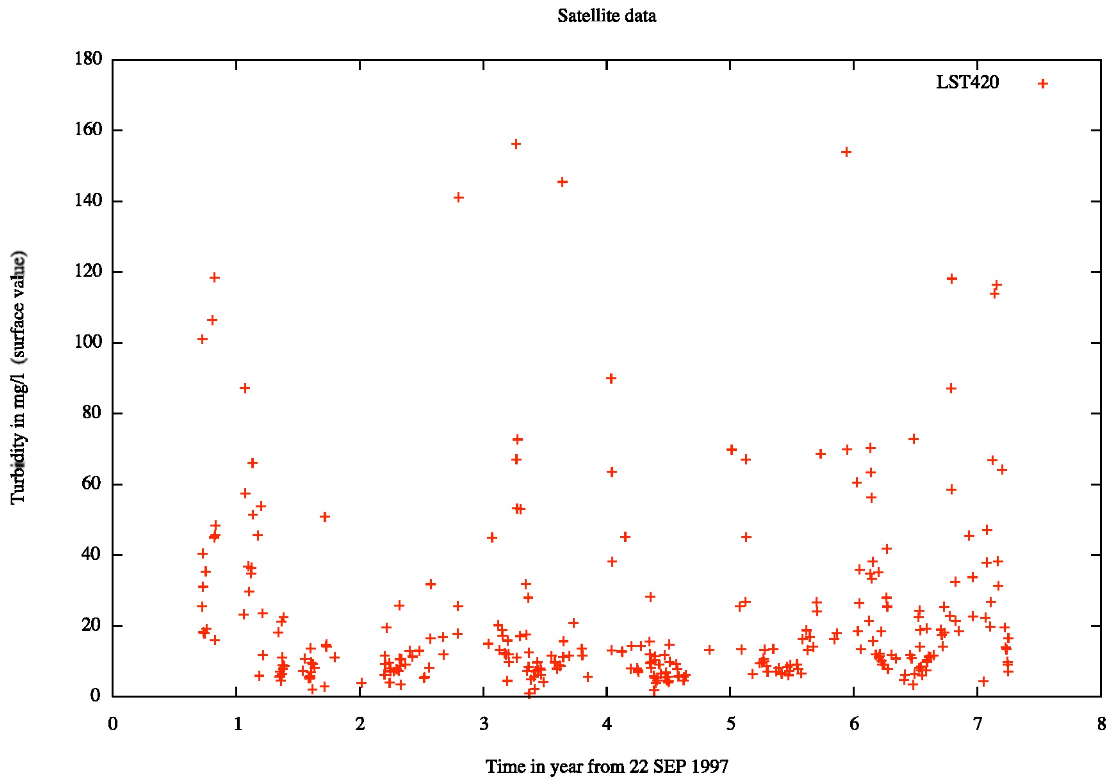


Figure A4-54 : Total suspended matter in mg/l for station LST 420. Data derived from SeaWifs 670 nm band

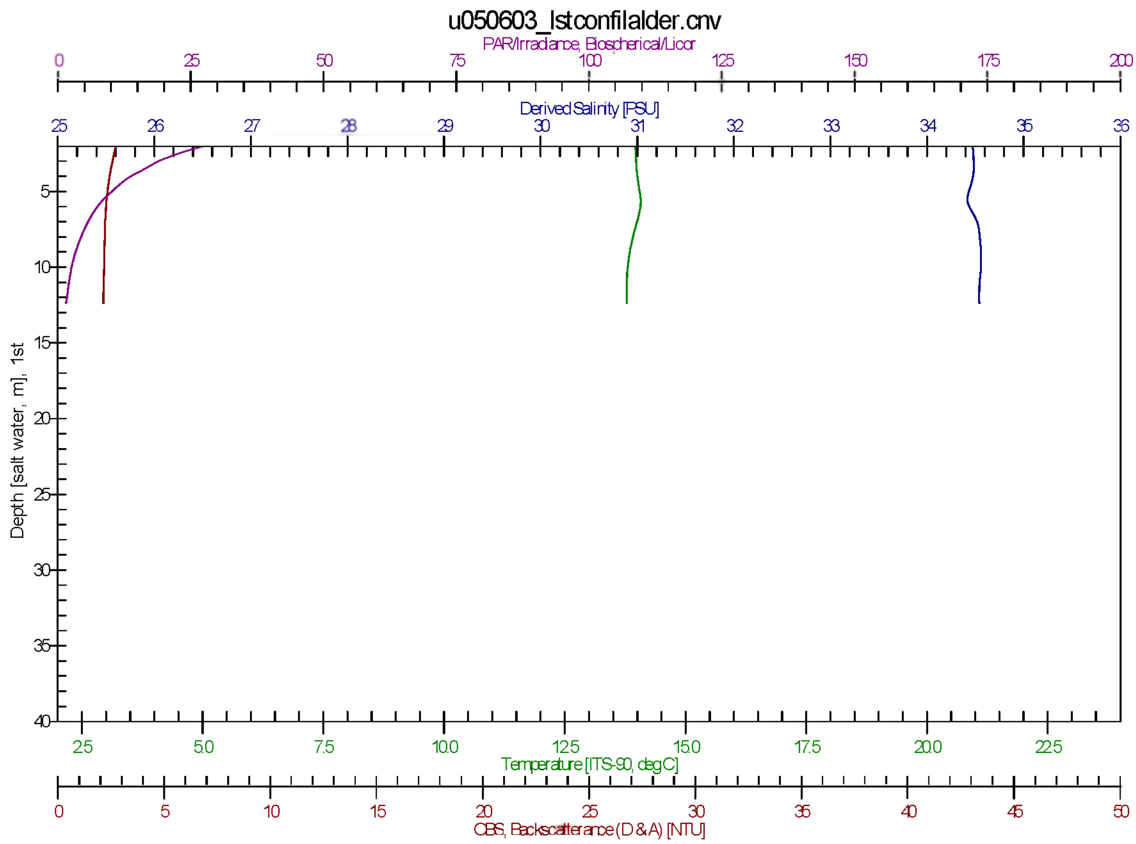


Figure A4-55

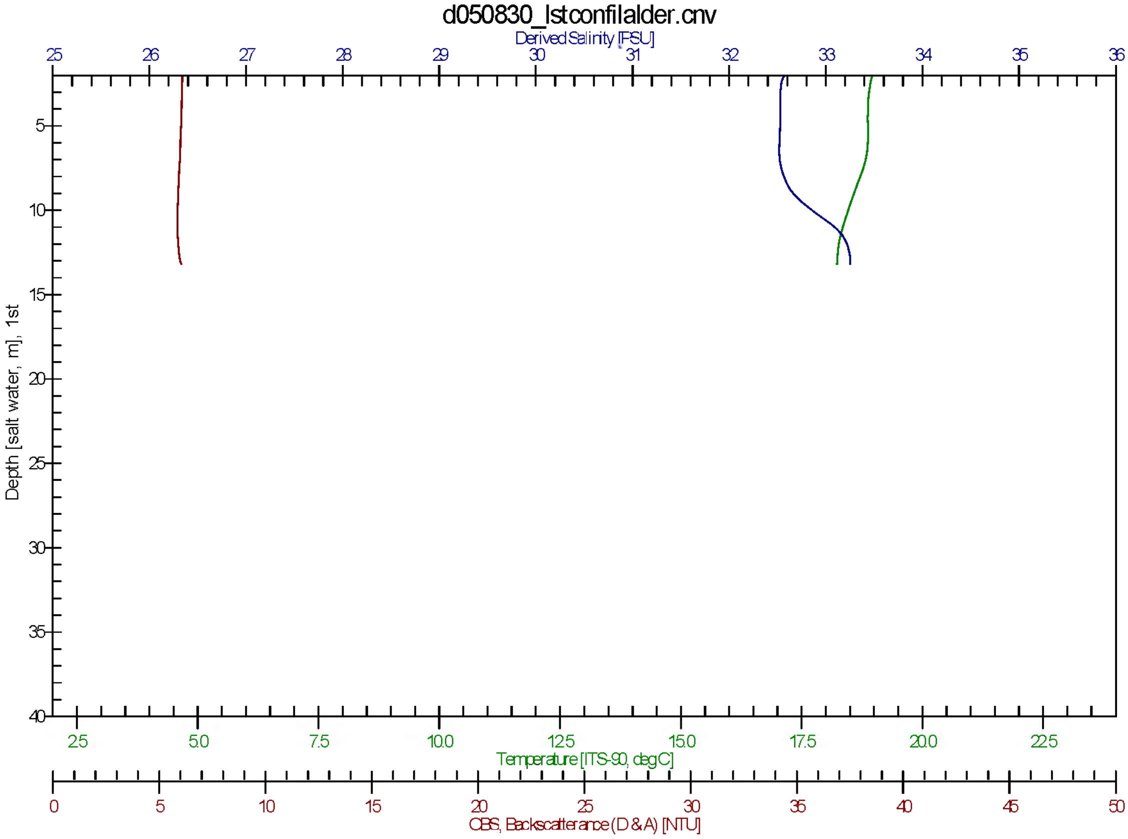


Figure A4-56

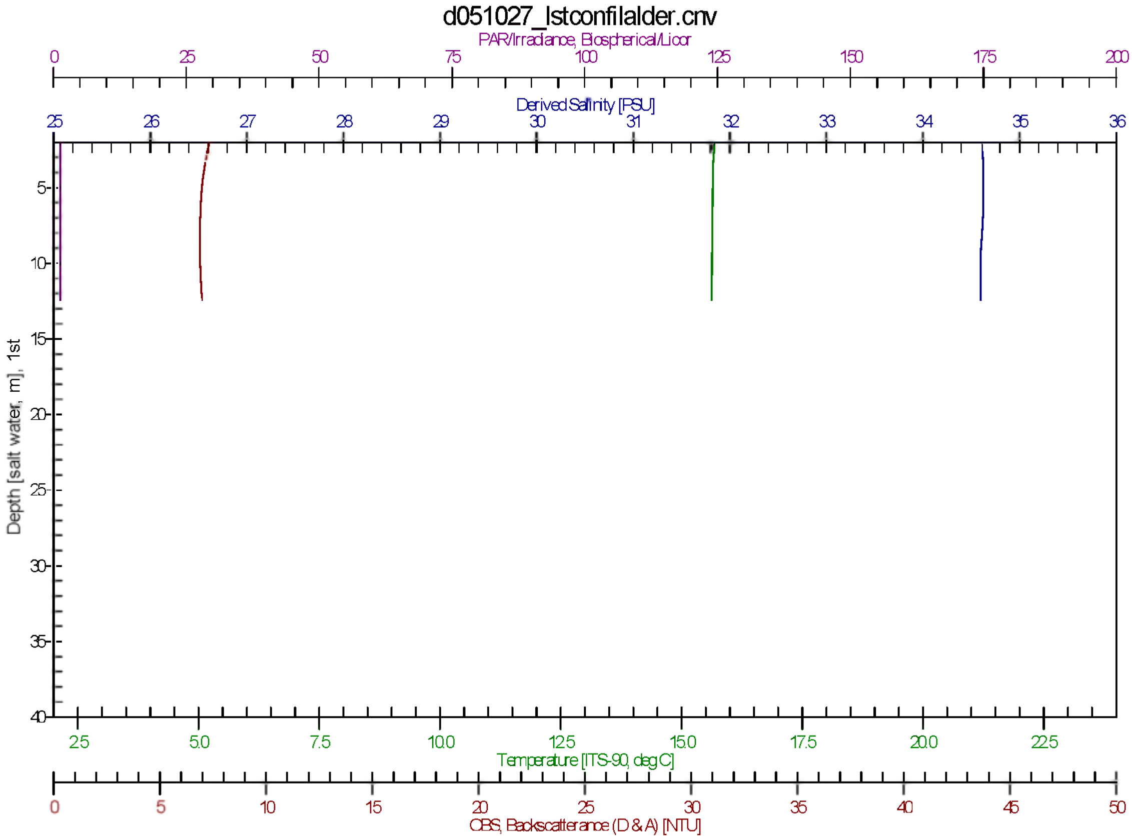


Figure A4-57

John Mahn
(WGS84 N 51°28,937 E 002°41,339)

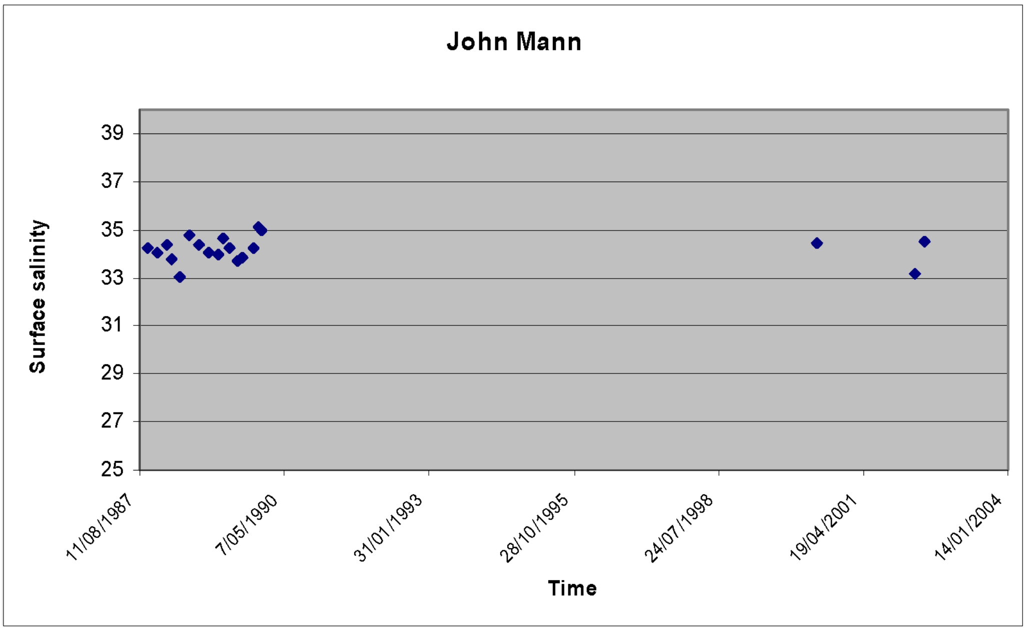


Figure A4-58: Surface Salinity. Station John Mann from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

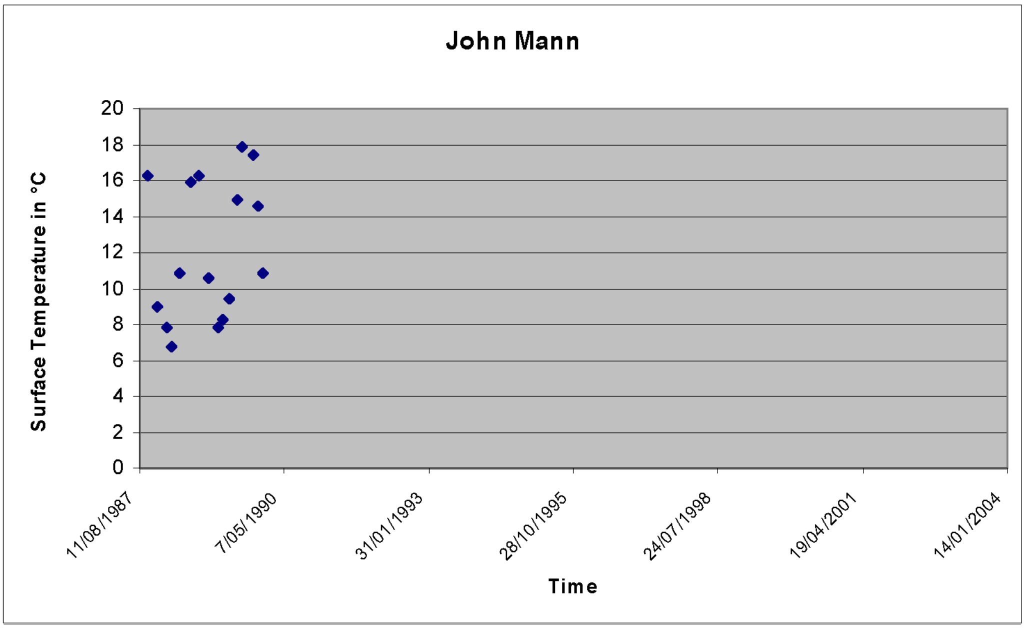


Figure A4-59: Surface Temperature. Station John Mann from database available data 5 NM from BMDC (Mumm) and IMERS (Vliz) data

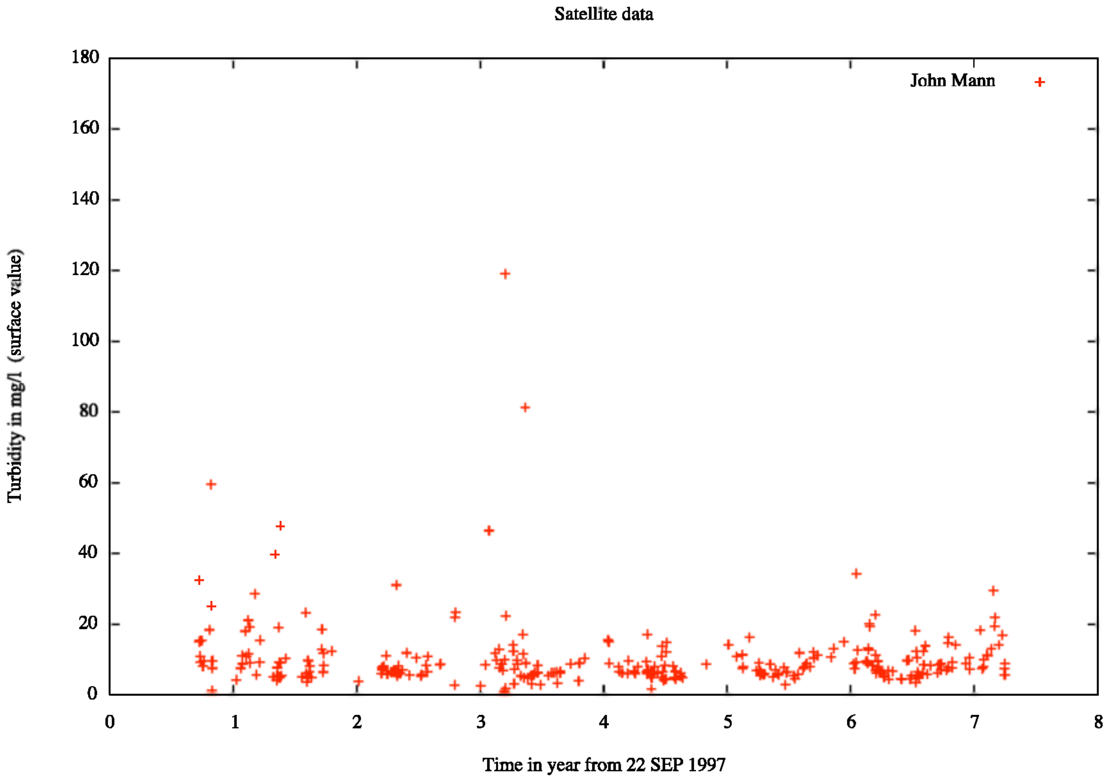


Figure A4-60: Total suspended matter in mg/l for station John Mann. Data derived from SeaWifs 670 nm band

JNM 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	6.33	6.79	6.55	33.28	33.45	33.38	0.24	
2	2.01	8.94	6.49	32.38	34.85	33.97	1.99	0.27
3	2.54	8.80	7.27	31.68	34.68	33.61	1.68	0.55
4	6.84	10.67	8.61	31.23	35.21	33.86	0.75	0.66
5	9.25	14.70	11.83	31.60	34.72	33.42	1.30	0.73
6	12.69	18.19	14.67	33.15	34.85	34.24	0.97	0.21
7	15.42	18.79	16.86	32.37	34.77	33.86	0.70	0.57
8	17.43	21.18	19.31	33.06	34.95	34.15	0.90	0.26
9	15.18	19.85	17.43	32.42	35.41	34.03	1.18	0.29
10	12.18	17.48	15.18	31.36	34.97	34.22	0.77	0.44
11	7.62	15.19	11.58	30.91	35.09	34.23	1.06	0.57
12	6.71	12.91	9.49	31.47	34.89	33.91	1.64	0.95

Table A4-13: John Mahn: monthly mean temperature and salinity from R/V Belgica underway data (1993-2006). Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

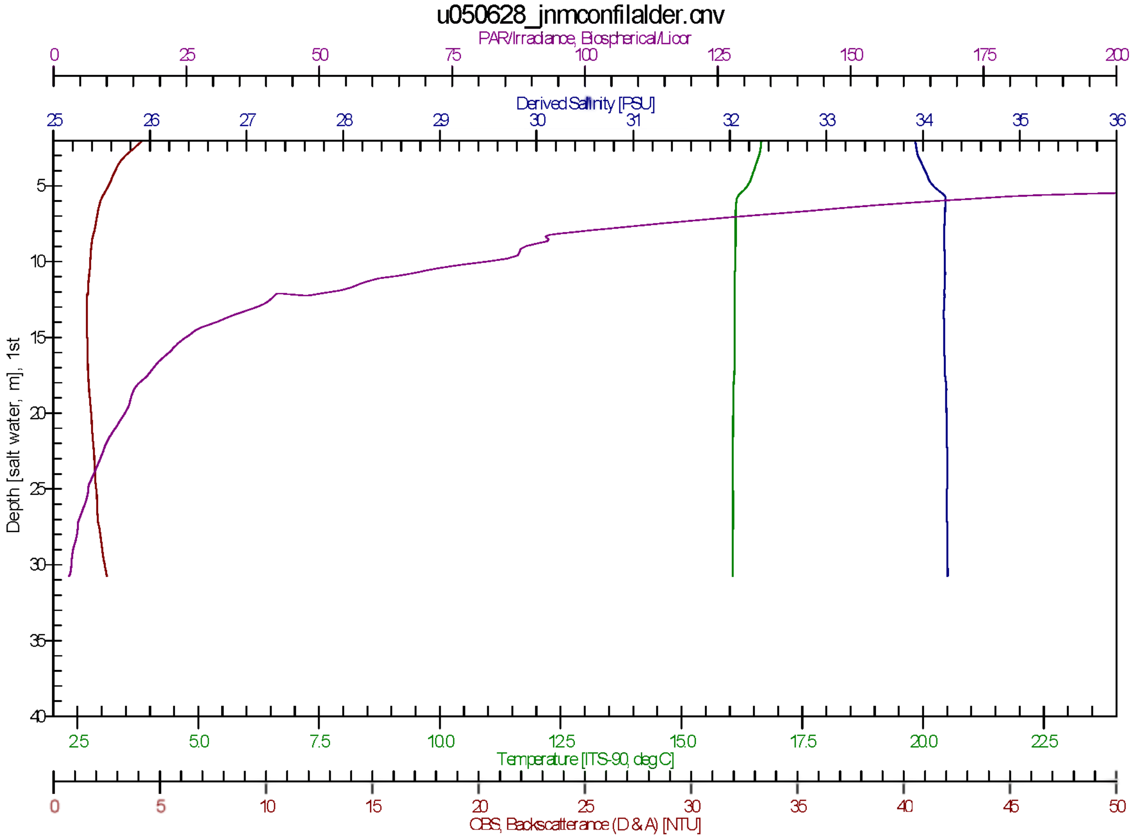

u050628_jnmconfilalder.cnv
PAR/Irradiance, Biospherical/Licor
0
25
50
75
100
125
150
175
200
Derived Salinity [PSU]
25
26
27
28
29
30
31
32
33
34
35
36
Depth [salt water, m], 1st
5
10
15
20
25
30
35
40
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
Temperature [ITS-90, deg C]
0
5
10
15
20
25
30
35
40
45
50
CBS, Backscatterance (D & A) [NTU]

Figure A4-61

Garden City
(WGS84 N 51°29,141 E 002°18,320)

BMDC/IMERS data unavailable for this wreck

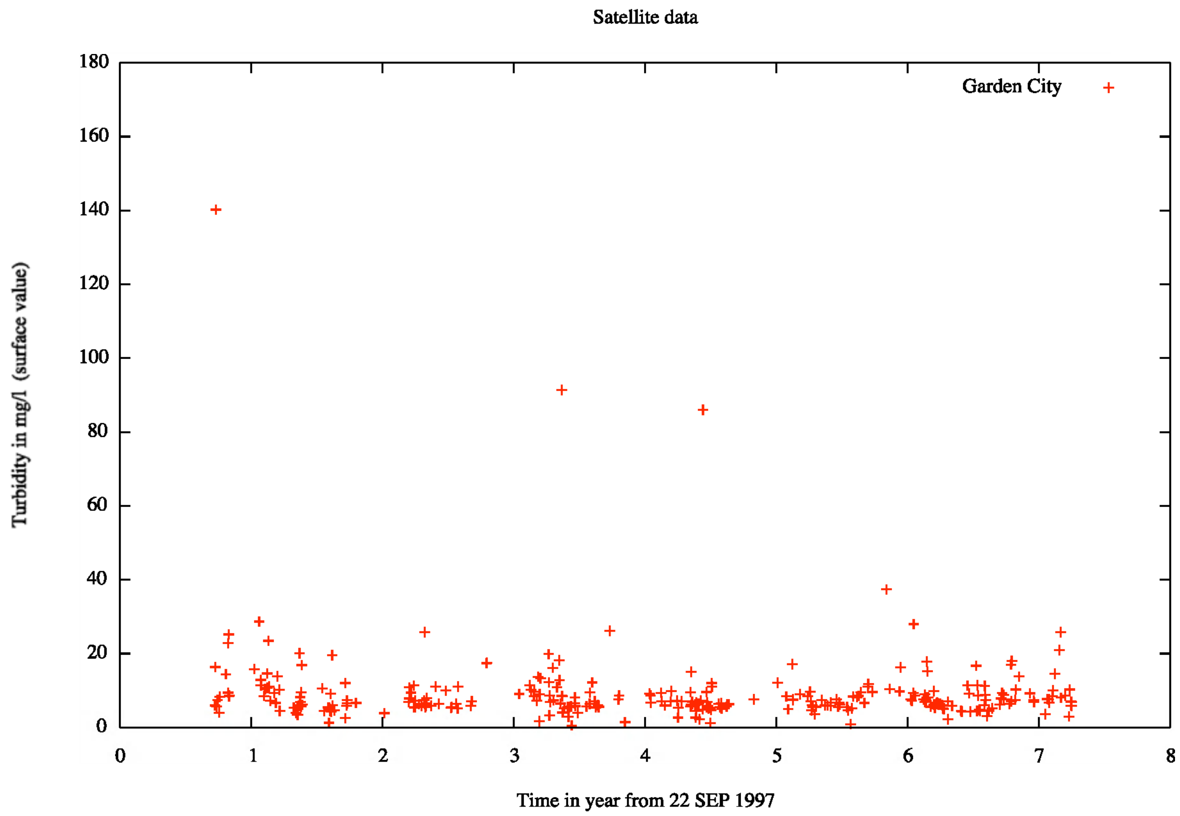


Figure A4-62: Total suspended matter in mg/l for station Garden city. Data derived from SeaWifs 670 nm band

GDC 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	5.38	8.13	6.74	34.57	35.14	34.93	1.31	
2	6.78	9.08	8.09	34.01	35.07	34.48	0.78	0.43
3	5.55	8.80	7.55	33.02	35.00	34.57	1.08	0.42
4	7.82	10.12	8.75	34.12	35.24	34.63	0.70	0.51
5	9.63	12.46	10.98	34.72	34.98	34.80	1.21	
6	12.45	15.33	13.98	34.39	34.97	34.66	0.88	0.19
7	15.78	16.51	16.19	34.12	34.75	34.45	0.23	0.35
8	17.56	20.08	18.45	33.87	35.10	34.62	0.64	0.40
9	16.29	18.93	17.50	34.10	34.88	34.68	0.84	0.14
10	13.69	17.45	16.37	34.30	35.00	34.73	1.00	0.18
11	9.09	13.71	12.26	34.58	35.05	34.86	1.49	0.11
12	7.91	12.48	10.38	34.46	34.99	34.76	1.49	0.18

Table A4-14: Garden City: monthly mean temperature and salinity from R/V Belgica underway data (1993-2006). Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

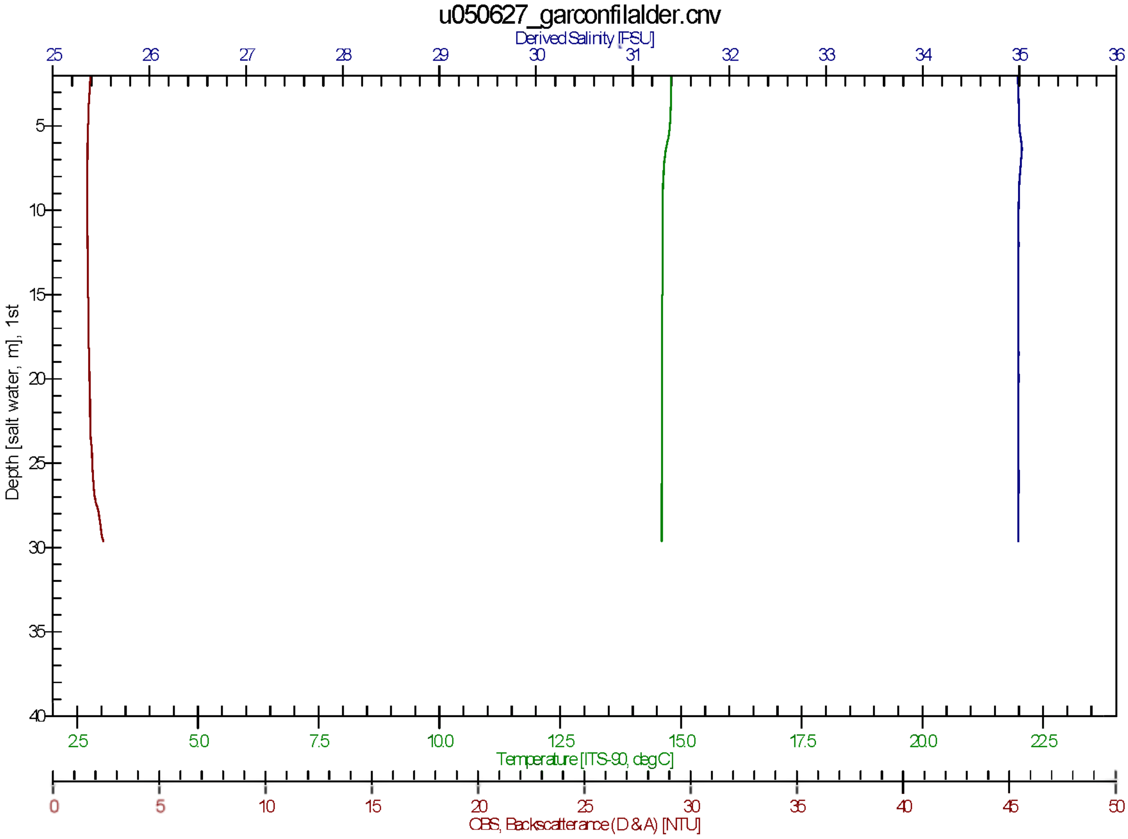

u050627_garconfilalder.cnv
Derived Salinity [PSU]
25
26
27
28
29
30
31
32
33
34
35
36
Depth [salt water, m], 1st
5
10
15
20
25
30
35
40
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
Temperature [ITS-90, deg C]
0
5
10
15
20
25
30
35
40
45
50
OBS, Backscatterance (D & A) [NTU]

Figure A4-63

Duc De Normandie
(WGS84 N 51°25,517 E 002°36,339)

BMDC/IMERS data unavailable for this wreck

DDN 93-06	T21 min	T21 max	T21	S21 min	S21 Max	S21	STDT21	STDS21
1	6.09	7.01	6.64	33.40	34.53	33.96	0.15	
2	2.05	9.07	6.90	32.23	34.96	33.83	1.93	0.07
3	3.34	8.83	6.92	31.73	34.90	33.97	1.60	0.49
4	7.00	10.27	9.11	31.83	35.22	33.79	1.01	0.82
5	9.18	14.16	11.44	31.62	34.80	33.88	0.96	1.02
6	12.76	18.44	14.37	33.03	34.94	34.28	1.06	0.32
7	15.34	18.95	16.62	30.95	34.76	34.03	0.79	0.62
8	17.67	21.53	19.35	32.63	35.01	34.15	0.98	0.45
9	14.98	20.13	17.72	32.42	35.17	34.28	0.94	0.33
10	10.60	17.51	15.37	32.86	35.00	34.20	1.03	0.44
11	7.71	13.65	11.57	31.45	35.13	34.14	1.26	0.79
12	6.25	12.68	9.28	31.63	34.92	33.87	1.78	0.95

Table A4-15: Duc De Normandie: monthly mean temperature and salinity from R/V Belgica underway data (1993-2006). Maximum and minimum observed values and Standard deviation of monthly means T21 and S21 are provided

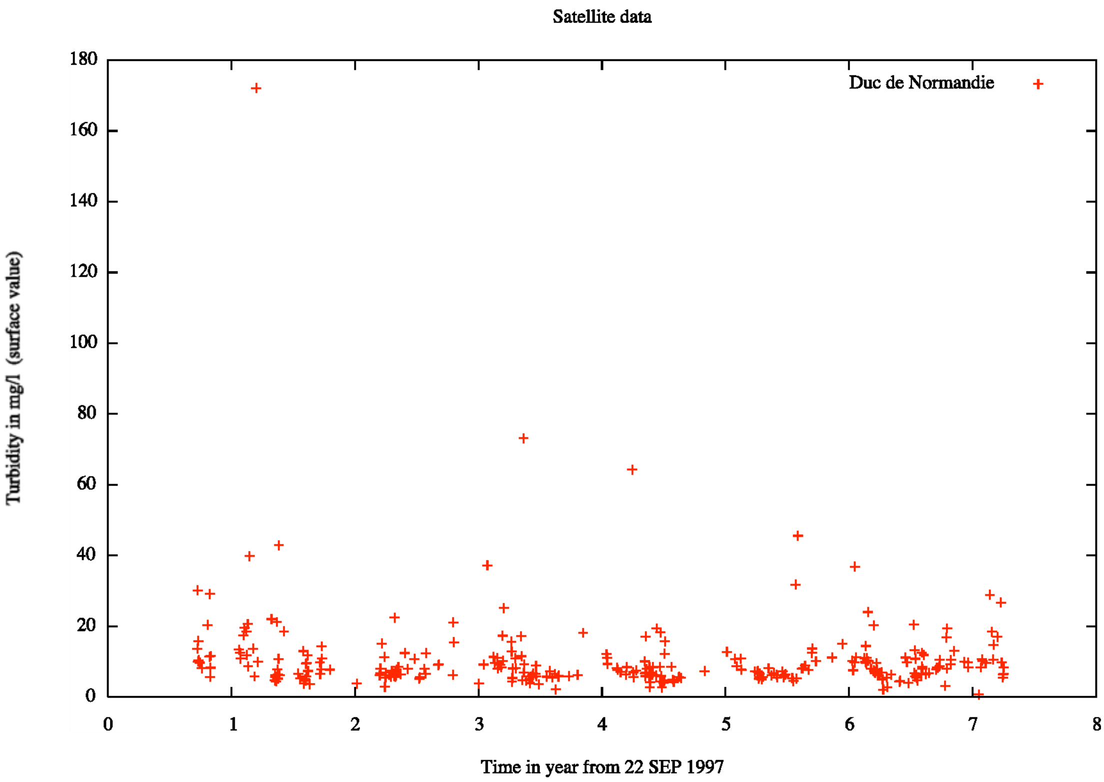


Figure A4-64: Total suspended matter in mg/l for station Duc de Normandie.
Data derived from SeaWifs 670 nm band

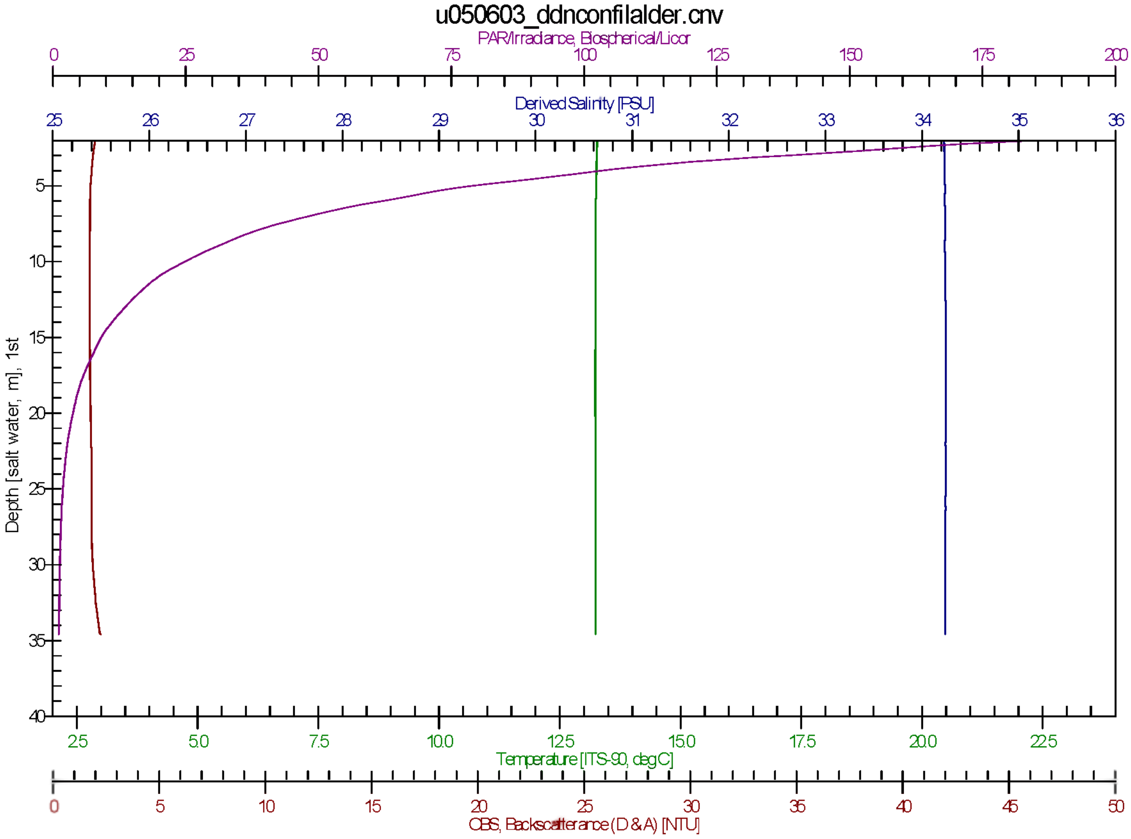

u050603_ddnconfilalder.cnv
PAR/Irradiance, Biospherical/Licor
0
25
50
75
100
125
150
175
200
Derived Salinity [PSU]
25
26
27
28
29
30
31
32
33
34
35
36
Depth [salt water, m], 1st
5
10
15
20
25
30
35
40
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
Temperature [ITS-90, deg C]
0
5
10
15
20
25
30
35
40
45
50
OBS, Backscatterance (D & A) [NTU]

Figure A4-65

Callisto
(WGS84 N 51°41,939 E 002°37,305)

This wreck is located very close by Birkenfels (less than 2.5 NM), therefore same abiotic data applies for Callisto and Birkenfels

Callisto wreck. Date 17 June 2005 HW at Oostende 09:57 and 22:17 (UT+2)

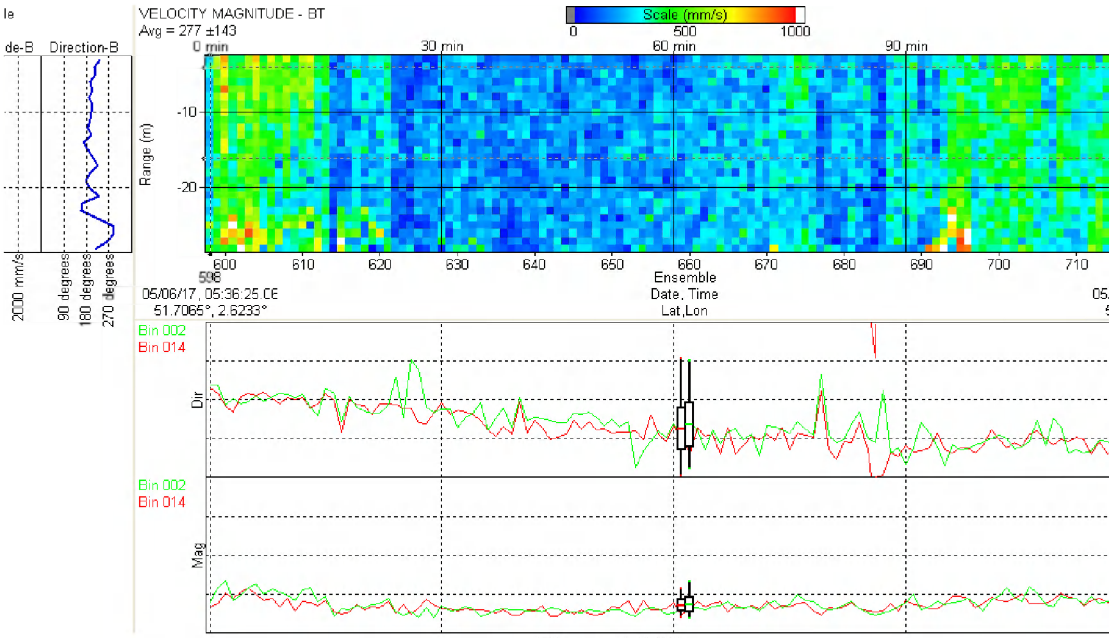


Figure A4-66

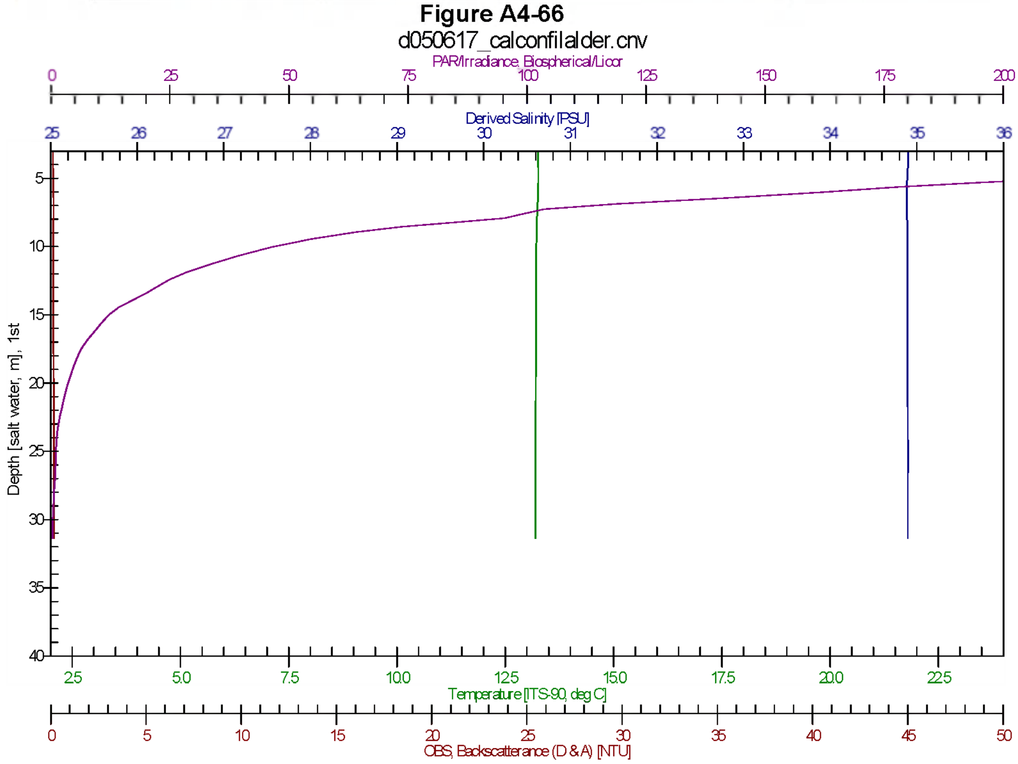


Figure A4-67

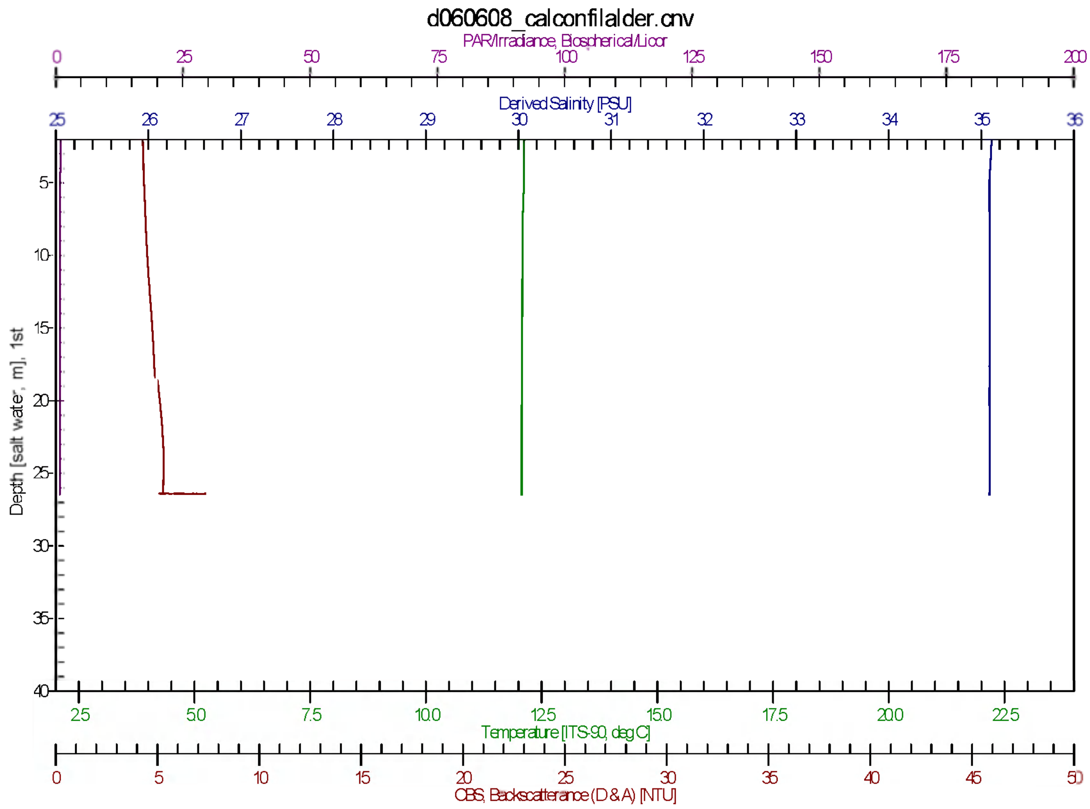


Figure A4-68

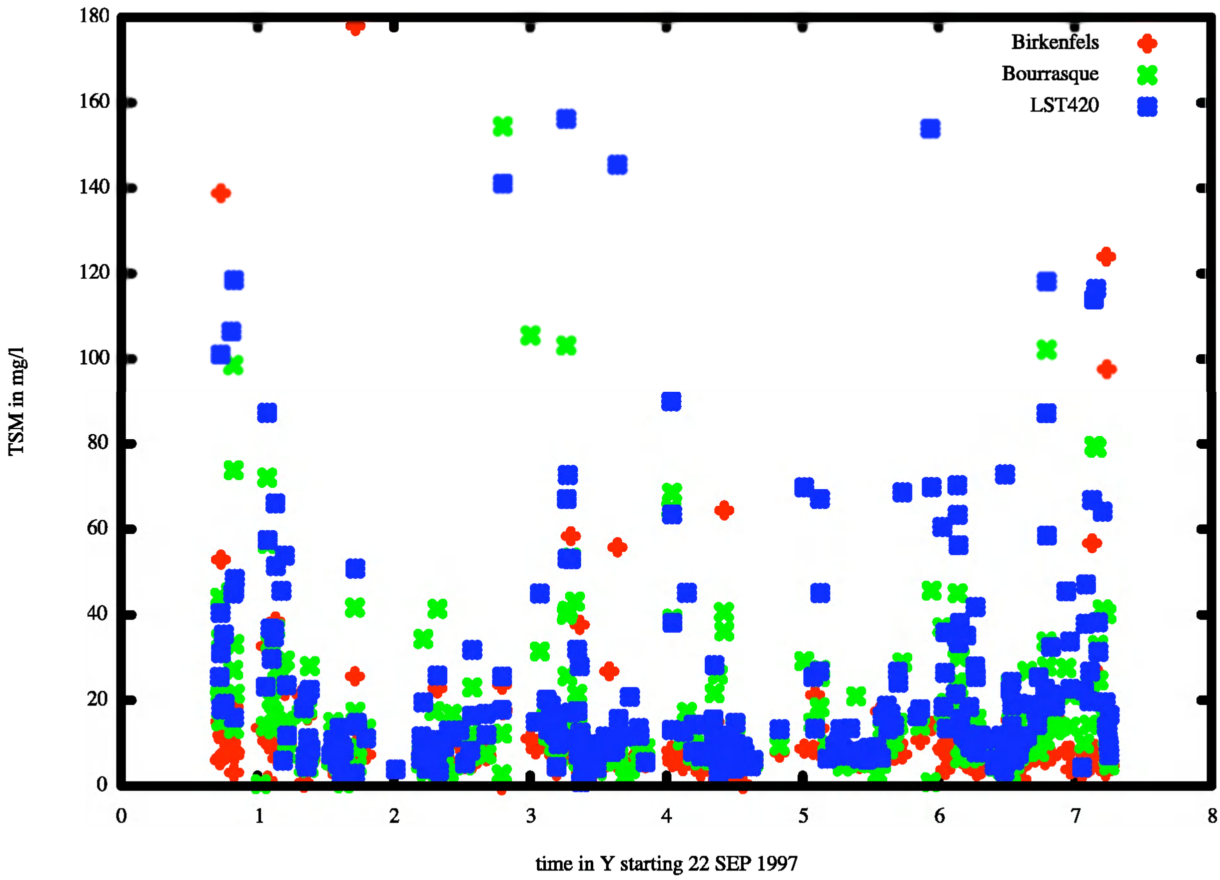


Figure A4-69: Comparison between Birkenfels, Kilmore and Lst 420 turbidity data derived from SeaWifs data 670 nm band

Annexe 5

Distribution of the epifaunal species on the ten shipwrecks investigated. Only the data collected between March and September are used. Sites are ordered from offshore to coastal zone. BRK: Birkenfels (N=25), CAL: Callisto (N=7), GAR: Garden City (N=3), JON: John Mahn (N=3), LCT: LCT 457 (N=3), KLM: Kilmore (N=32), BRQ: Bourrasque (N=23), LST: LST 420 (N=3), SPR: Sperrbrecher 142 (N=6). A simplified scale of dominance was attributed to the uncountable species: ● present, ●● abundant, ●●● dominant. * species found in the pebble community of the Dover Strait.

	BRK	CAL	GAR	JON	DUC	LCT	KLM	BRQ	LST	SPR
PORIFERA										
Dysidea fragilis (Montagu, 1818) *	●	●			●		●			
Esperiopsis fucorum (Esper, 1794)				●	●		●			
Halichondria cf *panicea* (Pallas, 1766)					●●		●			
Haliclona oculata (Pallas, 1766) *					●		●			
Haliclona sp.	●						●	●		
Hymeniacidon perlevis (Montagu, 1818)		●					●			
Leucosolenia sp. (Montagu, 1818)		●	●	●		●	●			
Myxilla rosacea (Lieberkühn, 1859)					●●		●			
Phorbas plumosus (Montagu, 1818)							●			
Sycon ciliatum (Fabricius, 1780) *	●	●●	●	●●	●●	●●	●●			
CNIDARIA										
Hydrozoa										
Bougainvillia muscus (Allman, 1863)								●		
Campanularia volubilis (Linnaeus, 1758) *	●							●		
Clytia gracilis (Sars, 1850) *								●		
Clytia hemisphaerica (Linnaeus, 1767) *	●						●	●		
Halecium sp. *							●			
Hydractinia echinata (Flemming, 1828) *	●							●	●	
Hydrallmania falcata (Linnaeus, 1758) *								●		
Laomedea flexuosa Alder 1857								●		
Nemertesia antennina (Linnaeus, 1758) *							●	●		
Obelia bidentata Clarke, 1875	●						●	●	●	
Sarsia eximia (Allman, 1859)		●								
Sertularia cupressina Linnaeus, 1758 *								●●		
Tubularia indivisa Linnaeus, 1758 *	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●●	
Tubularia larynx Ellis & Solander, 1786	●●					●●	●●	●●		

$Ind.m^{-2}$
0-10
10-100
100-1000
>1000

	BRK	CAL	GAR	JON	DUC	LCT	KLM	BRQ	LST	SPR
Anthozoa										
Actiniaria	100-1000	100-1000	100-1000	100-1000	100-1000	100-1000	100-1000	10-100	100-1000	100-1000
Alcyonium digitatum Linnaeus, 1758 *	0-10	0-10	10-100				10-100			
Diadumene cincta Stephenson, 1925	10-100						100-1000	100-1000		
Metridium senile (Linnaeus, 1767) *	0-10						0-10	100-1000	10-100	100-1000
PLATYHELMINTHE										
Eurylepta cornuta (Müller, 1776)					0-10					
Turbellaria			0-10			10-100	0-10			
NEMERTEA										
Baseodiscus delineatus (Delle Chiaje, 1825)		10-100	0-10			10-100	10-100			
Nemertinata sp.		0-10				100-1000				
Oerstedia dorsalis (Abildgaard, 1806)	10-100	10-100	10-100	10-100	100-1000	100-1000	100-1000	10-100	100-1000	
ANNELIDA										
Polychaeta										
Alentia gelatinosa (M. Sars, 1835)	0-10									
Autolytus sp.	10-100	0-10		0-10			10-100	0-10		
Cirratulidae		0-10								
Cirratulus cirratus (O.F. Müller, 1776)	0-10						0-10			
Cirratulus filiformis Keferstein, 1862							0-10	0-10		
Cirratulus sp.								0-10		
Cirriformia tentaculata (Montagu, 1808)	0-10				0-10		0-10			0-10
Dipolydora coeca (Oersted, 1843)							0-10			
Eteone longa (Fabricius, 1780) *							10-100			
Eteone picta Quatrefages, 1865								0-10		
Eulalia aurea Gravier, 1896	0-10	10-100					0-10			
Eulalia sp.	0-10						0-10			
Eulalia viridis (Linnaeus, 1768)	10-100	10-100	10-100	10-100	0-10	100-1000	10-100	0-10		0-10
Eumida sp.	0-10					10-100		10-100	10-100	
Eupolymnia nebulosa (Montagu, 1818)	0-10									
Eupolymnia nesidensis (Delle Chiaje, 1828)	0-10							0-10		
Eusyllis blomstrandi Malmgren, 1867	10-100		10-100	10-100	0-10	0-10	10-100	0-10		
Gattyana cirrhosa (Pallas, 1766)								0-10		
Harmothoe sp.	10-100	10-100	100-1000	100-1000	10-100	100-1000	100-1000	100-1000	10-100	0-10
Kefersteinia cirrata (Keferstein, 1862)	10-100	0-10	10-100	10-100	10-100	10-100	10-100	0-10		

$Ind.m^{-2}$
0-10
10-100
100-1000
>1000

	BRK	CAL	GAR	JON	DUC	LCT	KLM	BRQ	LST	SPR
Lanice conchilega (Pallas, 1766) *	10-100	10-100	10-100	10-100	10-100	10-100	10-100	10-100	100-1000	10-100
Lepidonotus squamatus (Linnaeus, 1758)	10-100	10-100	10-100	10-100	10-100	10-100	10-100		10-100	
Lumbrineris latreilli Audouin & Milne-Edwards, 1834							0-10			
Lumbrineris sp.							0-10			
Marphysa sanguinea (Montagu, 1815) *							0-10			
Neoamphitrite figulus (Dallyell, 1853)							0-10			
Nereimyra punctata (O.F. Müller, 1788)								0-10		
Nereis pelagica Linnaeus, 1758	10-100	10-100	10-100		0-10	0-10	0-10	10-100		10-100
Nicolea venustula (Montagu, 1818) *							0-10			
Nicomache sp.								0-10		
Ophelia sp.								0-10		
Owenia fusiformis Delle Chiaje, 1842							0-10			
Pectinaria koreni (Malmgren, 1866)							10-100			
Pholoe inornata Johnston, 1839	10-100	0-10					10-100			
Phyllodoce longipes Kinberg, 1866	0-10									
Phyllodoce mucosa Oersted, 1843	100-1000	0-10	0-10	100-1000	10-100	>1000	100-1000	100-1000	100-1000	100-1000
Phyllodoce sp.							0-10	0-10		
Pista cristata (O.F. Müller, 1776)	0-10									
Poecilochaetus serpens Allen, 1904							0-10	0-10		
Polycirrus sp.							0-10			
Polydora hoplura Claparède, 1870	0-10									
Polydora sp.	0-10						0-10	0-10		
Pomatoceros triqueter (Linnaeus, 1758) *	10-100	10-100	10-100	10-100	10-100	10-100	10-100	0-10		0-10
Proceraea sp.								0-10		
Procerastea halleziana Mallaquin, 1893	10-100						100-1000	0-10		
Procerastea perieri Gravier, 1900	0-10							0-10		
Sabellaria spinulosa Leuckart, 1849 *	10-100	100-1000	10-100	0-10	100-1000	10-100	10-100	0-10		
Scoloplos armiger (Allman, 1859)							0-10	0-10		
Sphaerodoropsis flavum Oersted, 1843 *						0-10	0-10			
Sphaerosyllis bulbosa Southern, 1914							0-10			
Sphaerosyllis sp.	0-10									
Sthenelais boa (Johnston, 1833) *		0-10					0-10	0-10		
Subadyte pellucida (Ehlers, 1864)	0-10	0-10	10-100	10-100			0-10			
Syllidae	0-10									

Ind.m^{-2}
0-10
10-100
100-1000
>1000

	BRK	CAL	GAR	JON	DUC	LCT	KLM	BRQ	LST	SPR
Syllis armillaris (O.F. Müller, 1776)	10-100	0-10	10-100			0-10	10-100			0-10
Syllis gracilis Grube, 1840	10-100	10-100	10-100	0-10	10-100	100-1000	10-100	10-100		10-100
Terebellidae	10-100									
Thelepus cincinnatus (Fabricius, 1780)	10-100						0-10			
Thelepus setosus (Quatrefages, 1865) *							0-10	0-10		
MOLLUSCA										
Gastropoda										
Aeolidiidae	0-10					0-10		0-10		
Archidoris pseudoargus (Rapp, 1827) *	0-10						0-10			
Catriona gymnota (Couthouy, 1838)								10-100		
Cerithiopsis tubercularis (Montagu, 1803)	0-10	0-10					0-10			
Crepidula fornicata (Linnaeus, 1758)	0-10						0-10			
Cuthona amoena (Alder & Hancock, 1845)							0-10			
Cuthona concinna (Alder & Hancock, 1843)							0-10			
Cuthona sp.	10-100	0-10	0-10	10-100	10-100	10-100	10-100	0-10	10-100	
Dendronotus frondosus (Ascanius, 1774) *	0-10		10-100	10-100	10-100	10-100	10-100	0-10	0-10	
Doto pinnatifida (Montagu, 1804) *							0-10			
Epitonium clathratulum (Kanmacher, 1798) *	10-100	0-10	10-100					10-100		
Eubranchus pallidus (Alder & Hancock, 1842)							0-10			
Eubranchus sp.	0-10						0-10	0-10	10-100	
Euspira pulchella (Risso, 1826) *	0-10	10-100					0-10	0-10		
Facelina bostoniensis (Couthouy, 1838)	0-10					10-100	0-10	0-10		
Lamellaria latens (Müller O.F., 1776)							0-10			
Nassarius incrassatus (Ström, 1768) *	10-100	10-100	10-100		0-10		10-100			0-10
Nassarius reticulatus (Linneaus, 1758)	0-10							10-100		
Raphitoma linearis (Montagu, 1803)	0-10						0-10			
Rissoidae	10-100	10-100					10-100	0-10		
Tergipes tergipes (Forskal, 1775)							0-10			
Tritonia cf *manicata* Deshayes, 1853							0-10			
Tritonia plebeia Johnston, 1828		0-10								
Trivia monacha (da Costa, 1778)							0-10			
Bivalvia										
Aequipecten opercularis (Linnaeus, 1758)	10-100	10-100	100-1000	0-10			10-100	0-10		
Heteranomia squamula (Linnaeus, 1758)	10-100	10-100	10-100	0-10	10-100		0-10			

Ind.m^{-2}
0-10
10-100
100-1000
>1000

	BRK	CAL	GAR	JON	DUC	LCT	KLM	BRQ	LST	SPR
Musculus sp.	0-10	10-100	10-100	0-10			0-10			
Mysella bidentata (Montagu, 1803)	0-10							0-10		
Mytilus edulis Linnaeus, 1758 *	100-1000	100-1000	100-1000	100-1000	100-1000	100-1000	>1000	10-100	10-100	
Ostreidae							0-10			
Venerupis geographica (Gmelin, 1791)	10-100									
Venerupis sp.	100-1000	0-10					0-10	0-10		
SIPUNCULA										
Golfingiida							0-10			
CRUSTACEA										
Copepoda										
Copepoda	0-10						0-10	10-100		
Cirripedia										
Acasta spongites (Poli, 1795)							0-10			
Balanus crenatus Bruguiére, 1789 *	10-100				10-100		0-10	100-1000		10-100
Verruca stroemia O.F. Müller, 1776 *							0-10			
Cumacea										
Cumacea	0-10							0-10		
Isopoda										
Janira maculosa Leach, 1814 *							0-10			
Pleurocrypta porcellanae Hesse, 1876							0-10			
Amphipoda										
Abludomelita obtusata (Montagu, 1813) *									0-10	
Atylus swammerdami (Milne-Edwards, 1830)			0-10					0-10	0-10	
Caprella linearis (Linnaeus, 1767) *	0-10							0-10		
Caprella tuberculata Guérin, 1836	100-1000	>1000	>1000	10-100	>1000		>1000	0-10		
Iphimedia nexa Myers & McGrath, 1987	0-10	0-10					0-10			
Jassa herdmani (Walker, 1893)	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Lysianassa ceratina (Walker, 1889)	0-10									
Melita hergensis Reid, 1939									0-10	
Metopa alderi (Bate, 1857)	0-10	100-1000	100-1000	100-1000	100-1000	100-1000	10-100	0-10	0-10	
Monocorophium acherusicum Costa, 1851								100-1000	100-1000	>1000
Monocorophium sextonae Crawford, 1937 *	100-1000	10-100	100-1000	100-1000	>1000	>1000	>1000	>1000	10-100	
Pariambus typicus (Kroyer, 1844)								0-10		
Phtisica marina Slabber, 1769	10-100	100-1000	>1000	>1000	100-1000	>1000	>1000	100-1000	10-100	

Ind.m^{-2}
0-10
10-100
100-1000
>1000

	BRK	CAL	GAR	JON	DUC	LCT	KLM	BRQ	LST	SPR
Pseudoprotella phasma (Montagu, 1804)								0-10		
Stenothoe marina (Bate, 1856)	10-100	10-100	10-100	100-1000	100-1000	100-1000	100-1000	10-100	100-1000	
Stenothoe monoculoides (Montagu, 1815)	100-1000	100-1000	100-1000	100-1000	100-1000	>1000	>1000	0-10	10-100	
Stenothoe sp.	10-100	100-1000					100-1000	10-100		0-10
Stenothoe valida Dana, 1855	10-100	100-1000	100-1000	>1000	100-1000	>1000	10-100	0-10		
Decapoda										
Anapagurus chiroacanthus (Lilljeborg, 1856)	0-10									
Atelecyclus rotundatus (Olivi, 1792)	0-10									
Ebalia tumefacta (Montagu, 1808) *							0-10			
Hyas araneus (Linneaus, 1758)	0-10									
Inachus phalangium (Fabricius, 1775) *							0-10			
Liocarcinus arcuatus (Leach, 1814)							0-10			
Liocarcinus holsatus (Fabricius, 1798) *								0-10		
Liocarcinus sp.	10-100	10-100					10-100	0-10		0-10
Macropodia parva Van Noort & Adema, 1985							0-10		0-10	
Macropodia rostrata (Linnaeus, 1761)	0-10									
Macropodia sp.							0-10			
Necora puber (Linnaeus, 1767) *	0-10						0-10			
Paguridae	0-10			0-10				0-10		
Pilumnus hirtellus (Linnaeus, 1761)	10-100	100-1000	10-100	10-100	10-100	10-100	100-1000	0-10	10-100	10-100
Pisidia longicornis (Linneaus, 1767) *	>1000	>1000	>1000	>1000	100-1000	100-1000	>1000	100-1000	10-100	100-1000
Thoralus cranchii (Leach, 1817)							0-10			
CHELICERATA										
Pyconogonida										
Achelia sp.			0-10				10-100			
Callipallene emacinata (Dohrn, 1881)							0-10			
Nymphon rubrum Hodge, 1865 *							0-10			
Pycnogonum littorale (Strom, 1762)			0-10					0-10		
BRYOZOA										
Cyclostomatida										
Crisia aculeata Hassall, 1841 *							•			
Disporella hispida (Fleming, 1828) *	•									
Plagioecia patina (Lamarck, 1816) *	•						•			
Cheilostomatida										

Ind.m^{-2}
0-10
10-100
100-1000
>1000

	BRK	CAL	GAR	JON	DUC	LCT	KLM	BRQ	LST	SPR
Bicellariella ciliata (Linnaeus, 1758) *							••			
Conopeum seurati (Canu, 1928)								0-10		
Electra pilosa (Linnaeus, 1767) *	•	••	••	••	••	••	••	•	•	
Scruparia chelata (Linnaeus, 1758)	•									
Scrupocellaria scruposa (Linnaeus, 1758)	•	•					••			
Ctenostomatida										
Alcyonidium cellarioides Calvet, 1900	•						•			
Nolella pusilla (Hincks, 1880)	•									
Vesicularia spinosa (Linnaeus, 1967)								0-10		
ECHINODERMATA										
Asteroidea										
Asterias rubens Linnaeus, 1758 *	0-10	10-100			0-10		10-100	0-10	0-10	10-100
Asterias rubens juv. Linnaeus, 1758 *		10-100	100-1000	100-1000	100-1000	100-1000	10-100		100-1000	
Echinoidea										
Clypeasteroidea							0-10	0-10		
Psammechinus miliaris (Gmelin, 1778)	100-1000	100-1000	10-100	10-100		10-100	10-100	0-10		
Ophiuroidea										
Amphipholis squamata (Delle Chiaje, 1829) *	10-100	100-1000	100-1000	10-100	10-100	10-100	100-1000	0-10	0-10	
Ophiothrix fragilis (Abildgaard,1789) *	100-1000	100-1000	>1000	100-1000	100-1000	100-1000	>1000	10-100	10-100	0-10
Ophiura albida Forbes, 1839 *	0-10									
Ophiura sp.							0-10			
CHORDATA										
Tunicata										
Ascidiacea	0-10									
Diplosoma sp.		•	••	••	••		••			
Molgula cf *occulta* occulta Kupffer, 1875	0-10	10-100					10-100			
Polyclinum aurantium Milne-Edwards, 1841		••					••			

$Ind.m^{-2}$
0-10
10-100
100-1000
>1000

Annexe 6

Distribution of the epifaunal species exclusively recorded between October and March. Sites are ordered from offshore to coastal zone. BRK: Birkenfels (N=7), KLM: Kilmore (N=14), BRQ: Bourrasque (N=12). A simplified scale of dominance was attributed to the uncountable species: ●: present, ●●: abundant, ●●●: dominant.

	BRK	KLM	BRQ
PORIFERA			
Mycale cf *macilenta* (Bowerbank, 1866)	●		
Suberites ficus (Esper, 1794)			●
ANNELIDA			
Polychaeta			
Eunicidae			
Lysidice ninetta Audouin & Milne-Ed., 1833			
NERMERTEA			
Tubulanus sp.			
MOLLUSCA			
Gasteropoda			
Tergipes tergipes (Forskal, 1775)			
CRUSTACEA			
Cumacea			
Bodotria arenosa (Goodsir, 1843)			
Amphipoda			
Amphilochus manudens Bate, 1862			
Decapoda			
Pagurus cuanensis Bell, 1845			

$Ind.m^{-2}$
0-10
10-100
100-1000
>1000

Annexe 7

List of additional species not sampled but observed by divers on shipwreck sites.

CNIDARIA

Anthozoa

Urticina felina (Linnaeus, 1767)
Sagartia sp.
Sagartiogeton undatus (Müller, 1788)
Actinothoe sphyrodeta (Gosse, 1858)

CRUSTACEA

Decapoda

Cancer pagurus Linnaeus, 1758

MOLLUSCA

Cephalopoda

Loligo vulgaris Lamarck, 1798 – eggs
Acanthodoris pilosa (Abildgaard in Müller, 1789)

BRYOZOA

Cyclostomatida

Bugula cf *turbinata* Alder, 1857

CHORDATA

Tunicata

Ascidiella scabra (Müller, 1776)
Clavelina lepadiformis Müller, 1776

PISCES

Dicentrarchus labrax (Linnaeus, 1758)
Gadus morrhua Linnaeus, 1758
Myoxocephalus scorpius (Linnaeus, 1758)
Parablennius gattorugine (Linnaeus, 1758)
Pollachius pollachius (Linnaeus, 1758)
Pollachius virens (Linnaeus, 1758)
Pomatoschistus sp.
Scomber scombrus Linnaeus, 1758
Spondyliosoma cantharus (Linnaeus, 1758)
Trisopterus luscus (Linnaeus, 1758)
Trisopterus minutus (Linnaeus, 1758)
Trachurus trachurus (Linnaeus, 1758)

Annexe 8


LES ÉPAVES
DE LA MER DU NORD
Découverte d'une biodiversité étonnante
PLUS DE 200 ÉPAVES DANS LES EAUX BELGES
Avec 64 km de long et une superficie d'à peine 3600 km² les côtes belges ne représentent que 0,5 % de la Mer du Nord. Une goutte d'eau dans un océan!
Cependant, 230 épaves reposent sur les fonds sablonneux des côtes belges.
En clair, une épave tous les 4 km.
La plupart de ces bateaux ont coulés lors des Ière et IIème guerres mondiales mais aussi lors de collisions dues à l'intensité du trafic maritime ou encore suite à de violentes tempêtes.
ÉTUDIER LES ÉPAVES: UN DÉFI À RELEVER
Accéder aux épaves n'est pas une mince affaire. Froid, forts courants, faible visibilité et météo changeante font partie des paramètres à gérer par les plongeurs scientifiques.
Plonger est nécessaire pour récolter les organismes qui vivent sur et autour de l'épave. Avec leurs instruments, les chercheurs mesurent aussi les paramètres de l'eau (t°, salinité, courant) et cartographient les épaves.
Il faut identifier, dénombrer, décrire la faune de l'épave, ses contraintes hydrodynamiques et les sédiments proches de celle-ci pour mieux comprendre cet environnement très particulier.
UNE BIODIVERSITÉ REMARQUABLE
Plus de 270 espèces ont été récoltées à ce jour sur seulement 10 épaves étudiées. Plusieurs espèces encore jamais rencontrées en Belgique ont été découvertes. Les épaves, constituent un nouvel habitat à part entière, tout à fait différent des sédiments qui les entourent.
Les épaves sont un terrain de chasse et de nursery pour les poissom. La densité de certaines espèces y est exceptionnelle.
LES ÉPAVES: UN CENTRE D'ACTIVITÉ INTENSE
La richesse de la vie marine créée par les épaves permet le développement de nombreuses activités humaines ayant d'importantes répercutions économiques. Des plongeurs et pêcheurs à la ligne ainsi que des bateaux de pêche professionnels visitent régulièrement les épaves.
Il est dans l'intérêt de tous d'assurer la pérennité de ces milieux particulièrement riches mais fragiles.
BELGIAN SCIENCE POLICY
BEWREMABI (Belgian Shipwrecks as Hotspot for Biodiversity) est un projet financé par la Politique Scientique Fédérale.
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SCHEEPSWRAKKEN
IN DE NOORDZEE
Onvermoede schatkamers van biodiversiteit
MEER DAN 200 WRAKKEN IN DE BELGISCHE WATEREN
De Belgische kust beslaat met zijn 64 km lengte en oppervlakte van 3600 km² slechts 0,5 % van de Noordzee.
Desondanks rusten 230 scheepswrakken op de zanderige bodem van het Belgisch kustgebied, wat neerkomt op zowat één wrak elke 4 km.
Het merendeel van deze schepen zonk gedurende de 1e en 2e wereldoorlog, maar ook door aanvaringen ingevolgde de hoge verkeersdrukte en door zware stormen.
ONDERZOEK VAN WRAKKEN: EEN UITDAGING OP ZICH
Scheepswrakken in de Noordzee zijn niet eenvoudig te bestuderen. Koude, stroming, slechte zichtbaarheid en wisselende weersomstandigheden moeten door de wetenschappelijke duikers getrotseerd worden.
De duikers verzamelen de organismen die op en rond de wrakken leven. Boven water brengen wetenschappers met behulp van diverse meetinstrumenten de wrakken in kaart en worden temperatuur, saliniteit en stroming van het water bepaald.
Om deze bijzondere onderwateromgeving beter te begrijpen wordt de dynamiek van het water bestudeerd en de fauna van zowel het wrak als de omliggende zandbodem op naam gebracht, geteld en beschreven.
EEN OPMERKELIJKE BIODIVERSITEIT
Tot op vandaag werden op 10 onderzochte wrakken reeds meer dan 270 soorten verzameld, waarvan enkele nog nooit eerder in België gevonden waren. De scheepswrakken vormen een op zichzelf staand habitat, totaal verschillend van de omringende zandbodem.
Vissen gebruiken de scheepswrakken als jachtterrein en kinderkamer, en enkele soorten komen er in buitengewoon hoge aantallen voor.
SCHEEPSWRAKKEN: CENTRA VOL ACTIVITEIT
Het rijke onderwaterleven op en rond de scheepswrakken maakt talrijke economisch belangrijke activiteiten mogelijk. Sportduikers, lijnvissers en vissersboten brengen regelmatig een bezoek aan de wrakken. Iedereen heeft er dan ook baat bij dat het voortbestaan van deze bijzonder rijke maar kwetsbare milieus verzekerd wordt.
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