ARTICLE 6: MACROBENTHOS OF SHIPWRECKS WITHIN AND AROUND THE BELGIAN WATERS AS A POTENTIAL FOOD RESOURCE FOR FISH POPULATIONS

The literature review of the thesis introduced the reader to the extended range of papers which concentrated their effort on artificial reefs dedicated to fisheries management. Most of theses papers dealt with artificial reefs which were planned, but the power of other structures like offshore platforms to attract fish was also highlighted. Indeed, shipwrecks also attract fish. As soon as we could enjoy correct visibility on Belgian shipwrecks, it appeared evident that a large amount of fish were attracted by every site we investigated. The most obvious species was *Trispoterus luscus* (pouting), but other commercially important species were frequently observed: *Pollachius pollachius*, *Pollachius virens*, *Gadus morhua* (cod) and D*icentrarchus labrax* (seabass). Other species typical of hard substrates were also censused by the divers, like *Parablennius gattorugine* or apparently *Crenilabrus melops*. There is no doubt that such species as *P. gattorugine* would not be present without the presence of shipwrecks because they are restricted to live on hard bottoms. In this case, the shipwrecks supply the essential habitat for a species to survive and help to produce more fish biomass. However, other species like the Gadidae mentioned above are not restricted to hard bottoms and are thus attracted by shipwrecks. We do not know why these fish are found so frequently and abundantly around reefs. What is an important question is to know if these species are just attracted without any other effect, or if they find in these places some advantage over living far from any reef. In other words, it would be interesting to know if shipwrecks allow producing more fish biomass. This would be an important discovery for fisheries management on Belgian waters.

These questions are not easily answered because they need a global approach on the fish stocks in the area.

One of the advantages that commercially important species could find living around Belgian shipwrecks, would be to feed on the large amount of biomass which develop on these sites. We decided to investigate the diet of *Gadus morhua* and *Dicentrarchus labrax* that were caught on shipwreck sites. This was achieved by following recreational fishermen who specifically go fishing on North Sea shipwrecks because of higher expected catches. An agreement was found to collect the stomachs of the catches.

We acknowledge that the following study has several weak points: (1) the number of collected samples is relatively low, (2) due to fishing regulations, only specimens above 30 cm could be collected; thus not results for juveniles/subadults are available, (3) it does not give take into account other factors than shipwreck species in attracting fish populations (like the provision of shelter).

However, the results will unambiguously show that at least *G. morhua* is using shipwreck fauna as food source.

MACROBENTHOS OF SHIPWRECKS WITHIN AND AROUND THE BELGIAN WATERS AS A POTENTIAL FOOD RESOURCE FOR FISH POPULATIONS

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1. INTRODUCTION

Shipwrecks of the Belgian and neighbouring waters attract fish species, in particular *Dicentrarchus labrax* (Linnaeus, 1758) (seabass) and *Gadus morhua* (Linnaeus, 1758) (cod). These two species, as well as Pollack, *Pollachius pollachius* (Linnaeus, 1758) and Pouting, *Trisopterus luscus* (Linnaeus, 1758), are targeted by sport fishermen whom specifically seek shipwrecks knowing that the aggregation of these fish yields better catches. The reasons why fish are attracted by shipwrecks are that they provide shelter from currents and predators (Danner *et al.*, 1994;Barshaw & Spanier, 1994), are possible recruitment sites (Bull & Kendall, 1994) and potentially harbour favoured prey (Pike & Lindquist, 1994). If any of these effects truly occur, it is likely that the biomass production of these species will be enhanced, either through better growth, improved gamete production or increased recruitment.

Recent biological surveys of shipwrecks in Belgian (Massin *et al.*, 2002; Zintzen *et al.*, 2006) and Dutch (Leewis *et al.*, 2000) waters have documented far greater macrobenthos biodiversity and biomass compared with the surrounding soft sediments (Van Hoey *et al.*, 2004). Not only is the biomass greater per unit area but the fauna is significantly different, most belonging to the sessile and slow moving fauna (Zintzen *et al.*, in prep.). Whether this fauna is a key factor for the attraction of fish is still poorly documented.

An investigation was carried out to discern whether the epifauna of shipwrecks was a key constituent of fish diet caught in the vicinity of these sites and if, as a consequence, these species are using the shipwreck environment as a feeding ground. Two commercially important fish species, cod and seabass, were targeted. The rejection of this hypothesis would allow concluding that fish are attracted by shipwrecks for other reasons that the increased biomass of hard substrate preys.

2. MATERIAL AND METHOD

The most direct way to investigate the importance of a potential food source is to study its status within the diet via stomach content analysis. Stomachs of *Dicentrarchus labrax* and *Gadus morhua* were sampled between 30th September 2004 and 30th March 2005 by accompanying sport fishing excursions specifically visiting shipwrecks. Sites were located between 30 and 55 km from the coast, on Belgian, French (distance from Belgian waters <10 km) and Dutch (distance from Belgian waters< 45 km) waters. 71 stomachs were collected; 26 from seabass and 45 from cod. The size of seabass and cod ranged from 30 to 60 cm and from 30 to 90 cm, respectively. Smaller stomachs could not be collected because the legislation in place did not allow for fishing specimens under 30 cm and results will apply to adult populations. Stomachs were kept in buffered formalin (final concentration: 4 %, pH 8.2-8.4) for 24-48h and then transferred to buffered alcohol. Prey items were sorted and identified under binocular microscope to the lowest taxonomic level possible to facilitate comparisons with the fauna of shipwrecks. Where possible, prey fish had their stomach contents identified also. After deducting empty stomachs there were 18 seabass and 40 cod samples available for analysis.

Dry weights of all food items were measured to the nearest mg after drying at 80°C until constant weight. Traditional methods, frequency of occurrence (%O) and the percentage weight (%W) (Hyslop, 1980), and multivariate methods, % Principal Component Analysis (%PCA; De Billy *et al.*, 2000) of dietary analysis were used to assess the feeding strategy and importance of prey items in the diets. All calculations for the %PCA were made with the software package ADE-4 (Thioulouse *et al.*, 1997). A similarity matrix of stomach samples was constructed using the Bray-Curtis similarity coefficient (Bray & Curtis, 1957). This was then subjected to one-way analysis of similarity (ANOSIM) tests to ascertain whether there were significant differences between the stomach content of the two species (Clarke & Warwick, 2001). Similarity percentages (SIMPER) tests were carried out to identify the prey items which contributed most to similarity and dissimilarity between fish species (Clarke & Warwick, 2001). All the results were compared with an extensive faunal list of shipwrecks macrobenthos from Belgian waters created during several campaigns (see Massin *et al.*, 2002 and Zintzen *et al.*, 2006), as well as with species list of soft sediment species collected in the framework of several projects (see Van Hoey *et al.*, 2004). The community of all these shipwrecks will be dominated by the hydrozoan *Tubularia indivisa* which allow for the development of a diversified epibenthic community. A species was considered being typical of shipwrecks if it was found in more than 10% of the samples taken from shipwrecks and found in less than 3% of the soft sediment samples. A species was deemed typical of soft sediment if it was present in more than 10% of the soft samples and less than 3% of shipwreck samples. When species occurred frequently (>10% of the samples) on soft sediment and shipwrecks, the species was considered identified on wrecks, but not exclusive to hard substrates.

3. Results

The seabass diet was dominated by fish, accounting for 95% of the weight (Table 1). The majority of individuals specialised on it. *Trachurus trachurus* was the only identified species. The other food items were soft bottom invertebrates which contributed minimally to the diet (Figure 1).

The cod diet was far more diverse. Of the 47 food items identified 24 had been identified on shipwrecks. Fish (Clupeidae and *Limanda limanda*) dominated by weight, followed by species identified on shipwrecks, among which some species restricted in their distribution to shipwrecks, such as *Necora puber*, *Ophiothrix fragilis*, *Pisidia longicornis* and *Pilumnus hirtellus* (Table 1). The most frequently occurring food items after fish were *Tubularia indivisa* and *Jassa herdmani*, two species which characterise shipwreck communities. *P. longicornis* and *O. fragilis* occurred in large numbers in some stomachs: three stomachs included 91, 63 and 49 individuals of *Pisidia longicornis*, a species repeatedly taken with *P. hirtellus* or *Liocarcinus holsatus*; one stomach contained solely *O. fragilis* with a total of 89 individuals. The most important food items to cod were fish, *N. puber*, *B. undatum*, *O. fragilis* and *P. longicornis* (Figure 1 and Table 1).

The one-way ANOSIM showed that the seabass and cod stomach samples did not actually significantly differ from each other. However, the significance level was low at 10.8% with an R-value of 0.068. A SIMPER test revealed that the average similarity for seabass was 35.88% and 17.36%

Table 1. Frequency of occurrence (%O), dry weight (DW) and percentage of dry weight (%DW) of prey items found in the stomachs of Seabass (*Dicentrarchus labrax*, N=18) and Cod (*Gadus morhua*, N=40) taken on shipwrecks from Belgian waters. * Taxa identified on wrecks or found exclusively on hard substrates. ** Taxa identified on wrecks, but not exclusive to hard substrates. na: not applicable.

PREY CATEGORY	COD			SEABASS		
	% O	DW (g)	% DW	% O	DW (g)	% DW
PISCES						
Unidentifed sp.	55	170.894	58.706	66.67	27.538	64.38
Trachurus trachurus (Linnaeus, 1758)	-	-	-	38.89	13.243	30.96
Limanda limanda (Linnaeus, 1758)	5.0	60.021	20.619	-	-	-
Clupeidae sp.	2.5	7.009	2.408	-	-	-
Congridae sp.	2.5	0.021	0.007	-	-	-
CRUSTACEA						
Unidentified sp.	5	0.331	0.114	-	-	-
DECAPODA						
Necora puber (Linnaeus, 1767)*	12.5	10.824	3.718	-	-	-
Unidentified Brachyura sp.	17.5	5.79	1.989	11.11	0.862	2.02
Pisidia longicornis (Linneaus, 1767)*	22.5	4.233	1.454	-	-	-
Pilumnus hirtellus (Linnaeus, 1761)*	7.5	3.933	1.351	-	-	-
Liocarcinus holsatus (Fabricius, 1798)**	7.5	2.002	0.688	-	-	-
Liocarcinus sp.**	5	1.414	0.486	-	-	-
Paguridae sp.**	7.5	0.697	0.239	-	-	-
Crangon crangon (Linnaeus, 1758)	10	0.368	0.126	-	-	-
Anomura sp.	2.5	0.244	0.084	-	-	-
Pagurus bernhardus (Linnaeus, 1758)**	2.5	0.168	0.058	5.56	0.371	0.87
Portunidae sp.**	2.5	0.145	0.05	-	-	-
Unidentified Decapoda sp.	5	0.07	0.024	-	-	-
Unidentified Natantia sp.	10	0.028	0.01	-	-	-
Galathea intermedia Lilljeborg, 1851	2.5	0.016	0.005	-	-	-
AMPHIPODA						
Jassa herdmani (Walker, 1893)*	25	0.283	0.097	-	-	-
Caprella linearis (Linnaeus, 1767)*	2.5	0.02	0.007	-	-	-
Unidentified Amphipoda sp.	12.5	0.016	0.005	-	-	-
Caprella tuberculata Guérin, 1836*	5	0.005	0.002	-	-	-
Phtisica marina Slabber, 1769*	2.5	<0.001	<0.001	-	-	-
Stenothoe marina (Bate, 1856)**	2.5	<0.001	<0.001	-	-	-
Corophiidae sp.	2.5	<0.001	<0.001	-	-	-
ANNELIDA						
Arenicola marina (Linnaeus, 1758)	5	1.487	0.511	-	-	-
Unidentified Polychaeta sp.	2.5	0.085	0.029	-	-	-
Sabellaria spinulosa Leuckart, 1849*	5	0.024	0.008	-	-	-
Nephtyidae sp.	2.5	0.015	0.005	-	-	-
ECHINODERMATA						
Ophiothrix fragilis (Abildgaard,1789)*	10	5.972	2.052	-	-	-
Unidentified Ophiuroidea sp.	2.5	0.055	0.019	-	-	-
Echinocardium cordatum (Pennant, 1777)	2.5	0.005	0.002	-	-	-

PREY CATEGORY	COD			SEABASS		
	% O	DW (g)	% DW	% O	DW (g)	% DW
CNIDARIA	15	3.071	1.055	-	-	-
Tubularia indivisa Linnaeus, 1758*	22.5	0.017	0.006	-	-	-
Tubularia sp.*	2.5	0.011	0.004	-	-	-
Plumulariidae sp.	2.5	<0.001	<0.001	-	-	-
Sertularia sp.**	10	<0.001	<0.001	-	-	-
Unidentified Hydrozoa sp.	2.5	0.111	0.038	-	-	-
Actiniaria sp.**						
MOLLUSCA	-	-	-	5.56	0.643	1.5
Unidentified Prosobranchia	5	6.178	2.122	-	-	-
Buccinum undatum Linnaeus, 1758	2.5	0.167	0.057	-	-	-
Nassarius incrassatus (Ström, 1768)*	2.5	0.023	0.008	-	-	-
Euspira pulchella (Risso, 1826)**						
BIVALVIA	12.5	1.41	0.484	5.56	0.116	0.27
Shell fragments	5	0.756	0.26	-	-	-
Aequipecten opercularis (Linnaeus, 1758)*	2.5	0.097	0.033	-	-	-
Pectinidae sp.**						
TUNICATA	2.5	0.001	<0.001	-	-	-
Diplosoma sp.*						
OTHER	32.5	3.082	1.059	-	-	-
Unidentified fragments						
NON FOOD ITEMS	5	na	na	-	-	-
Fibre	15	na	na	5.56	na	na
Rock	10	na	na	-	-	-
Sand	2.5	na	na	-	-	-
Wood	7.5	na	na	5.56	na	na
Pomatoceros triqueter (Linnaeus, 1758) tubes	12.5	na	na	-	-	-
Sabellaria spinulosa tubes						

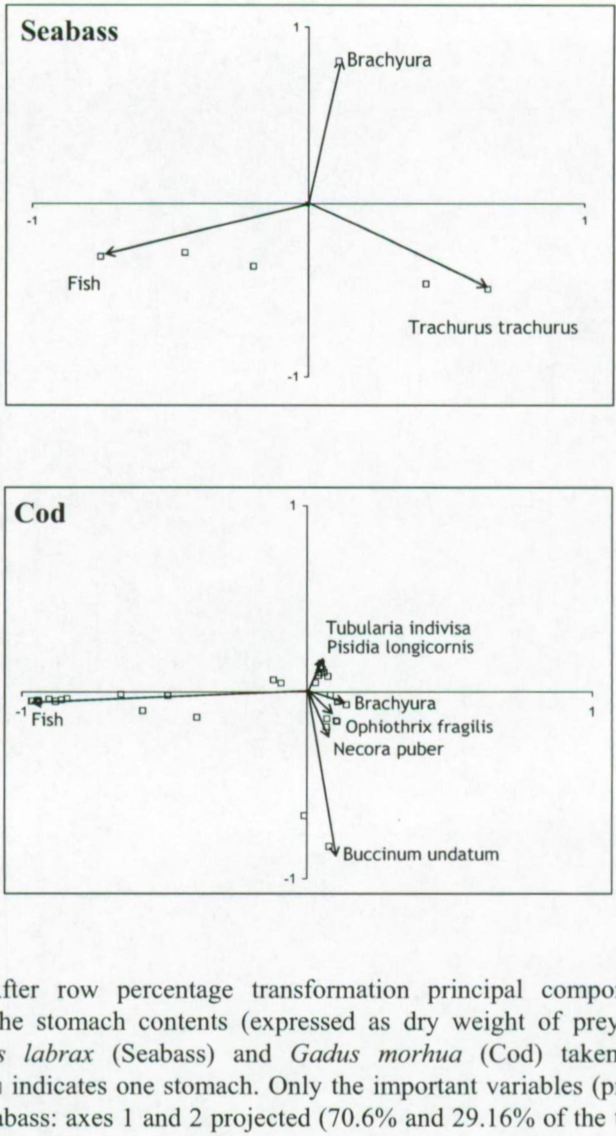

Figure 1. After row percentage transformation principal component analysis (%PCA) of the stomach contents (expressed as dry weight of prey items) from *Dicentrarchus labrax* (Seabass) and *Gadus morhua* (Cod) taken on Belgian shipwrecks. □ indicates one stomach. Only the important variables (prey items) are projected. Seabass: axes 1 and 2 projected (70.6% and 29.16% of the total variation respectively). Cod: axes 1 and 5 (38.83% and 6.15% of the total variation).

for cod with unidentified fish contributing the most to the similarity within each group.
Only 9 *T. trachurus*, 3 unidentified fish and the 1 Clupeid had reached a low enough level of digestion to extract the content of their stomachs. The lengths of the *T. trachurus* ranged from 8.2 cm to 10.2 cm. The unidentified fish and clupeid were of similar size and maturity. The amphipod *Atylus swammerdami* (Milne-Edward, 1830) was identified in the *T. trachurus* stomachs. Species of the genus *Bathyporeia* were identified from the unidentified fish. These are amphipods which also inhabit fine sediment of low mud content. Finally, the mysid *Schistomysis spiritus* (Norman, 1860) was identified from the Clupeid stomach.

4. Discussion

The largest part of the diet for seabass was composed of fish and Brachyura. The unidentified fish are most probably *Trachurus trachurus*. The *T. trachurus* identified in the seabass stomachs were probably members of the stock abundant in the Southern North Sea during autumn (Pawson, 1995). It seems that the seabass temporarily specialised on the stock at that time. The fat and energy content of adult *T. trachurus* is highest in autumn (Abaunza *et al.*, 2003) which would make them more appealing to the seabass. Interestingly, Kelly (Kelley, 1987) did not observe *T. trachurus* in the seabass he sampled around the southern and western coast of the UK. The question of whether seabass prey on *T. trachurus* at the shipwreck location is not easily answered. *Trachurus trachurus* has been identified as a resident (at least temporarily) of shipwrecks (Massin *et al.*, 2002) and the specimens from the seabass stomachs were easily identifiable suggesting they were taken in the habitat they were caught in, i.e. the shipwrecks. However, seabass are a highly mobile fish making it possible that food, although still being quiet fresh when collected near shipwrecks, was swallowed in a different habitat. The lengths of the *T. trachurus* ranged from 8.2 cm to 10.2 cm, which classes them as juvenile (Knijn *et al.*, 1993). The stomach content of *T. trachurus* specimens suggested they spend time foraging in a habitat of fine sand. Thus it is most probable that *T. trachurus* forage at soft sediments surrounding the shipwrecks. Therefore seabass either prey on *T. trachurus* at the soft sediments or at the shipwrecks when *T. trachurus* return for shelter. In consequence, it is probably the presence of *T. trachurus* in the close vicinity of shipwrecks which attracts seabass. The attraction of *T. trachurus* could be linked to the shelter from currents and predators provided by the structure of shipwreck.

Essentially, the prey items found to be most important to the cod were fauna which grow largest (Fish, *Necora puber* or *Buccinum undatum*) or form dense aggregations on shipwrecks (*Tubularia* sp, *Jassa herdmani*, *Pisidia longicornis* and *Ophiothrix fragilis*, see Zintzen *et al.*, 2006). This is probably because food selection by cod is primarily governed by the size of the food items in relation to their own size (Daan, 1973). The cod's diet gradually shifts from crustaceans to fish with increasing size because for small cod, fish are towards the upper limit of prey size whereas they can easily find crustaceans of an appropriate size. In contrast, crustaceans would be below the appropriate size for larger cod (Daan, 1973). If prey size is important to cod then it is hard to see why these fish would consume *Tubularia sp.*, *Jassa herdmani* and the other amphipods and cnidarians identified on shipwrecks. Given their size they are unlikely to be important. Therefore given the very small quantities yet relatively high occurrence in stomachs, in conjunction with their vast coverage on shipwrecks, it is most probable that *Tubularia* sp., *J. herdmani*, *P. longicornis* and *O. fragilis* were consumed accidentally whilst cod preyed on Brachyura for example. Their presence within the stomach of cod, can thus be considered to be a marker of the feeding ground, rather than a selected food item for cod. The occurrence of the other amphipods and hydrozoans in the stomachs may be due to the fact that the species diversity is very high in the *T. indivisa* community found on the shipwrecks (Zintzen *et al.*, 2006). However, a number of individuals had no *Tubularia sp.* in their stomach while a high number of the small decapod *P. longicornis* and the ophiuroid *O. fragilis* were found. It suggests that these cod were specifically targeting these two species because they are closely associated with *Tubularia sp* which acts as a support for other species on shipwrecks.

In conclusion, although cod and seabass are often found together in large shoals surrounding shipwrecks, different reasons might explain why these fish aggregate there. Stomach content analysis suggests that these species might have different predation strategies: while cod appears to prey on organisms coming to feed on wreck epifauna, seabass are more likely to feed on other fish species seeking shelter or attracted by other parameters resulting from the presence of the wreck.

Shipwrecks of the Belgian and neighbouring waters attract fish species, in particular *Dicentrarchus labrax* (Linnaeus, 1758) (seabass) and *Gadus morhua* (Linnaeus, 1758) (cod). These two species, as well as Pollack, *Pollachius pollachius* (Linnaeus, 1758) and Pouting, *Trisopterus luscus* (Linnaeus, 1758), are targeted by sport fishermen whom specifically seek shipwrecks knowing that the aggregation of these fish yields better catches.

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