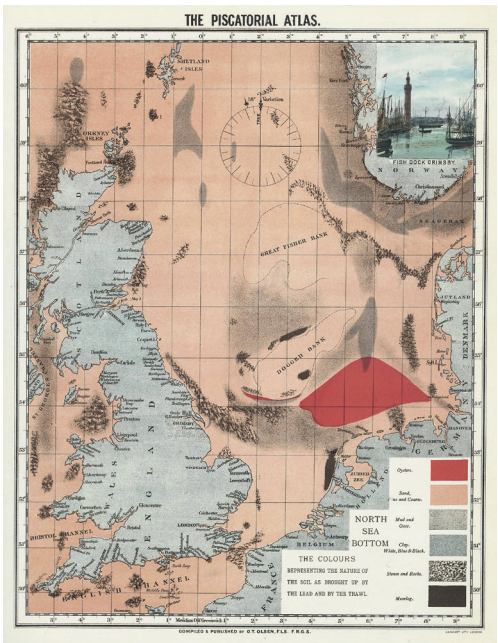
ECOLOGICAL RELEVANCE OF SHIPWRECKS IN THE NORTH SEA

Wouter Lengkeek, Joop Coolen, Adriaan Gittenberger & Niels Schrieken

This paper reports on observations made during wreck dive expeditions in 2010-2012, in order to investigate the ecological relevance of shipwrecks on the Dutch Continental Shelf (DCS). Shipwrecks are biodiversity hotspots. The number of species recorded on shipwrecks is similar to the number of species found in soft bottoms of the entire DCS. The soft substrates, however, represent a vastly larger habitat on the DCS than the shipwrecks. Amongst many other taxa, juvenile and large Atlantic cod, linear skeleton shrimp, goldsinny wrasses and leopard spotted gobies were found in the shipwreck habitats. The presence of these important species and their absence from many other habitats, illustrate that shipwrecks function as key habitats, nurseries, and refugia that are rare or absent anywhere else in the Netherlands.

INTRODUCTION

In the present day situation, the seabed on the Dutch Continental Shelve (DCS) is mostly characterized by sandy or silty soft substrate. Natural hard substrates are very rare, and larger areas with hard substrates can only be found in the form of gravel on the Cleaver Bank (Bos et al. 2010) and the Borkum Reef Ground (Bos & Paijmans 2012).



Closer to the Dutch coast, only small patches of rocks and gravel can be found (pers. obs. Joop Coolen). The benthic communities on the DCS are therefore generally typical for soft substrate habitats. However, in the 19th century the situation was different. Old sea maps and research reports show that 20-35% of the seabed on the DCS was covered with hard substrate habitats (fig. 1) (Olsen 1883, Whitehead & Goodchild 1909). These hard substrates mainly consisted of oyster beds, coarse peat banks (called moorlog) and glacial erratics. The moorlog on the Dogger Bank for example, was so abundant that trawl fishermen considered it a great annoyance and when caught they broke it up in pieces before discarding it (Whitehead & Goodchild 1909). These extensive habitats were home to benthic reef communities, mostly consisting of taxa typical for hard substrates.

Figure 1. Map of different types of substrate on the North Sea seabed by Olsen (1883). Explanation of legend from top to bottom: Red = oyster bank, pink = sand, gray = mud, gray 2 = clay, black and white marbeled = rocks, black = moorlog (ice age erratics).
Figuur 1. Kaart van de verspreiding van verschillende substraat typen in de Noordzee door Olsen (1883). De legenda van hoog naar laag: Rood = oesterbank, roze = zand, grijs = slib, zwart-wit geblokt = stenen, zwart = moorlog (veenpakketten uit ijstijd).

Figure 2. Research locations.
Figuur 2. Onderzoekslocaties.

Natural hard substrates disappeared from the DCS, presumably through natural erosion, oyster diseases and bottom disturbing fisheries. Other human activities, however, resulted in an abundance of artificial hard substrates, such as shipwrecks, foundations of offshore installations and coastal defence works such as seawalls and harbour entrances. It is hypothesized that the benthic reef communities that once inhabited the natural hard substrates now find refuge on these artificial substrates. Although hard substrate habitats are relatively rare, they appear to play a significant role from a biodiversity point of view, as they harbour a relatively high diversity of species native to the Dutch marine waters, compared to the soft substrate habitats. On many artificial habitats, such as shipwrecks, wind farms, purposefully build artificial reefs and seawalls, extensive and highly diverse reef communities have been observed (Leewis & Waardenburg 1991, Leewis & Hallie 2000, Van Moorsel 1998, Gittenberger et al. 2010, Zintzen & Massin 2010, Lengkeek et al. 2011, Bouma & Lengkeek 2012, Krone et al. 2012, Schrieken et al. 2013). During biodiversity surveys on shipwrecks in the southern North Sea up to 250 taxa were recorded, a species richness similar to that encountered in soft substrate surveys of the entire DCS (Daan & Mulder 2006, Lengkeek et al. 2011, Schrieken et al. 2013). Shipwreck habitats on the DCS can therefore be considered as biodiversity hotspots (Leewis et al. 2000).

Published biodiversity surveys of artificial habitats such as shipwrecks in the North Sea are relatively rare, but studies that focus on the ecological relevance of such habitats in the North Sea are, to our knowledge, non-existent. Considering the diverse benthic communities on shipwrecks, it is likely that these habitats have important roles such as nurseries for young fish or refuges for vulnerable native species for which nowadays little to no natural habitats are available in the Dutch waters. To illustrate the roles artificial habitats may have, this paper reports on field observations of some species that live on shipwrecks.

METHODS

The wreck diving methods used for data gathering, including a description of the Dogger Bank expedition 2011 are presented in Schrieken et al. (2013). In addition, this study presents results from:
Multiple dives carried out in 2010, 2011 and 2012, during which the WWI shipwrecks of the HMS Hogue (position: 52°15'.314N 003°41'.329E), HMS Aboukir (position: 52°15'.196N 003°40'.822E) and HMS Cressi (position: 52°15'.216N 003°41'.490E) were visited;
- Two dives on the SS Elbe wreck in 2010 (position: 52°35'.511N 003°27'.096E);
- One dive in 2012 on the SS Vittorio Z wreck (position: 53°18'.845N 004°51'.963E);
- One dive in 2012 on an unknown wreck numbered #1802 (position 51°53.445N 002°19.463E);

Figure 3. A young cod using a shipwreck as its refuge. Photo Adriaan Gittenberger.
Figuur 3. Een jonge kabeljauw die een wrak als zijn refugium gebruikt. Foto Adriaan Gittenberger.

Figure 4. Goldsinny wrasse *Ctenolabrus rupestris.* Photo Adriaan Gittenberger.
Figuur 4. Kliplipvis *Ctenolabrus rupestris.* Foto Adriaan Gittenberger.

Figure 5. Leopard spotted goby *Thorogobius ephippiatus.* Photo Adriaan Gittenberger.
Figure 5. Luipaardgrondel *Thorogobius ephippiatus.* Foto Adriaan Gittenberger.

- One dive in 2012 on the Tubantia wreck (position 51°49.817N 002°49.087E);
- One dive in 2012 on an unknown wreck nick-named the Mammoth wreck (position: 52°06'.111N 003°03'.881E).

An overview of all sites that where visited for this study is provided in figure 2.

RESULTS

During the wreck dives we regularly encountered large numbers of Atlantic cod *Gadus morhua* of 0,5-1 m body length and observed higher numbers of cod on shipwrecks at greater distance from the coast than on near shore shipwrecks. A shoal of approximately 100 larger individuals was encountered on the Dogger bank far offshore shipwreck Jeanette Christina on the Dogger bank (Schrieken et al. 2013). Furthermore, we found juvenile (0+) cod (fig. 3), specimens of a few centimetres long, on all twelve shipwrecks that were visited and none were found during the four dives that were made on sandy bottoms during the expedition in 2011 (Schrieken et al. 2013).
Two other fish species for which the shipwreck appeared to be their favourite habitat are the goldsinny wrasse *Ctenolabrus rupestris* and the leopard spotted goby *Thorogobius ephippiatus* (fig. 5). The goldsinny wrasse (fig. 4) was encountered on every wreck dive except for the on ss Vittorio z

Figure 6. Ghost shrimp *Caprella linearis*. Photo Adriaan Gittenberger.
Figuur 6. Spookkreeft *Caprella linearis*. Foto Adriaan Gittenberger.

Figure 7. Egg-capsules of the squid *Alloteuthis subulata*. Photo Adriaan Gittenberger.
Figuur 7. Eierkapsels van de pijlinktvis *Alloteuthis subulata*. Foto Adriaan Gittenberger.

(fig. 2). The leopard spotted goby, was encountered on the wreck sites HMS Hogue, HMS Aboukir, HMS Cressi, SS Elbe, SS Vittorio Z, Tubantia, the Mammoth wreck and the wreck #1802 (fig. 2).

In addition to these fish species, the wrecks were found to be an important habitat for invertebrate species that are not commonly found in soft substrate habitats (see also Schrieken et al. 2013). During the Dogger Bank expedition in June 2011, for example, the native linear skeleton shrimp *Caprella linearis* (Linnaeus, 1767) (fig. 6) was encountered in large numbers on the shipwreck HMS Aboukir. The alien invasive species *Caprella mutica* (Schurin, 1935), which is by far the most abundant *Caprella* species along the Dutch coast, was not encountered.

In addition the wrecks formed a habitat for species that need hard substratum to lay their egg capsules on, like the squid *Alloteuthis subulata* (Lamarck, 1798) (fig. 7) and the whelk *Buccinum undatum* (Linnaeus, 1758) (fig. 8). The wrecks were also inhabited by species that prefer to live in holes like the brown crab *Cancer pagurus* (Linnaeus, 1758) (fig. 8) and the lobster *Homarus gammarus* (Linnaeus, 1758) (see also Schrieken et al. 2013).

DISCUSSION

Key habitat

The Atlantic cod is heavily over fished in various regions including the DCS and holds the IUCN status of 'vulnerable'. Nowadays large specimens

Figure 8. The brown crab *Cancer pagurus* in front of the white egg-capsules of the whelk *Buccinum undatum.* Photo Adriaan Gittenberger.
Figuur 8. De Noordzeekrab *Cancer pagurus* naast de witte eierkapsels van de wulk *Buccinum undatum.* Foto Adriaan Gittenberger.

are rare on the DCS, but we encountered them on shipwrecks and in higher numbers at large distances from the coast than on near shore shipwrecks. It appears from various studies that Atlantic cod prefer hard substrate habitats and can stay within close proximity of a single structure for long periods of time (Winter et al. 2010). When living on a shipwreck, cod are effectively protected from bottom trawl fisheries (bottom trawlers generally avoid shipwrecks). They are, however, not protected from line (angling) and gill net fishing. Because the latter two are predominantly near shore fishing activities, this forms a plausible explanation of why we observed more of the larger cods at larger distances from the coast than on near shore wreck sites.

The goldsinny wrasse *Ctenolabrus rupestris* (fig. 4) is a common inhabitant of hard substrate areas in the Atlantic region. It presumably had an extensive natural habitat on the DCS some 130 years ago when natural hard substrates were abundant. It was not encountered during recent large-scale fisheries surveys on the DCS. The species lacks from the most recent list of Dutch marine fishes (Sportvisserij Nederland 2009). Furthermore, for at least the last five years (but possibly much longer) it has not been encountered in the International Bottom Trawl Survey and the Demersal Fish Survey programmes that are carried out yearly on the DCS soft bottom habitat (www.surveyswageningen-imares.wur.nl). Our findings that the goldsinny wrasses were present on almost all investigated wrecks, indicate that it has not disappeared from the Dutch waters. The wrecks have become the key habitat for this native Dutch species and it is possible that the species would have disappeared entirely from the DCS if there were no shipwrecks. This also accounts for other species that entirely depend on the presence of hard substrate habitats, like the leopard-spotted goby *Thorogobius ephippiatus*. Similarly to the goldsinny wrasse, the leopard-spotted goby is absent in published species lists of Dutch marine fishes and is not encountered in large-scale fish surveys. Just like the goldsinny wrasse, however, this native species has not disappeared from the Dutch waters. It is in fact widespread, inhabiting a large number of wrecks. In addition to these fishes, the wrecks form a key habitat for species that prefer to live in a hard substrate habitats with crevices and holes like the common brown crab *Cancer pagurus* (fig. 8) and the lobster *Homarus gammarus* (see also Schrieken et al. 2013).

Nursery

Our observations suggest that juvenile (0+) cod (fig. 3) are attracted to shipwrecks, and possibly use them as nursery grounds. This is supported by a study from Nova Scotia, that demonstrated that post-settlement survival and subsequent juvenile (0+) densities were significantly higher in

more structurally complex habitats, compared to other habitats (Tupper & Boutiller 2011). Shipwrecks provide the most structurally complex habitats on the DCS and may therefore provide valuable habitats for cod recruitment. Cod is not the only species for which shipwrecks may serve as nurseries or breeding areas. During our studies we encountered the egg capsules of various species like the whelk *Buccinum undatum* and the squid *Alloteuthis subulata* (fig. 7) on the shipwrecks. These species need hard substrata to attach their egg capsules to, and are therefore depended on the existence of wrecks and other hard substrata on the DCS.

Refugium

The linear skeleton shrimp *Caprella linearis* once was a common inhabitant of hard structures on the DCS including coastal defence works such as sea walls and harbour defences. In recent years however, *C. linearis* is very rarely encountered and seems to have disappeared from many of its former habitats (Gittenberger et al. 2010). The alien invasive Japanese skeleton shrimp *Caprella mutica*, which was first recorded on the DCS in 1994 (Cook et al. 2007) is now commonly present in most of the former habitats of *C. linearis*. Furthermore it has been shown that the larger *C. mutica* behaves aggressively towards *C. linearis*, which results in significantly higher mortality rates for *C. linearis* (Shucksmith et al. 2009). We found a shipwreck where *C. linearis* lives in high numbers (fig. 6), but no *C. mutica*. This suggests that shipwrecks may serve as refugia for native species that have been outcompeted by alien species in most of the habitats where they used to occur along the Dutch coast.

Ecological relevance

As our observations illustrate, shipwrecks are important for Dutch marine biodiversity in general because they form hard and complex substrates in a sandy bottom environment. In two published shipwreck surveys from the North Sea, 130-250 species where found on shipwreck habitats (Van Moorsel et al. 1991, Mallefet et al. 2009). Circa 90% of these species are hard substrate specialists and do not occur on sandy bottoms (Mallefet et al. 2009). By comparison, in soft-bottom surveys that covered the entire DCS, 181-231 species were encountered (Daan & Mulder 2006). The wrecks, although they cover less than 1% of the Dutch North Sea, thus account for a large percentage of the marine diversity of species present in the Dutch North Sea. A similar situation was recorded in the state of Pernambuco, Brazil, where shipwrecks form the only hard substrate habitat in a sandy bottom environment (Ameral et al. 2009). Similar high levels of biodiversity were found there, and it was concluded that the wrecks contribute significantly to the species richness of the local marine environment. In Europe this is typically the case for the Dutch, Belgian and German North Sea. Along the coasts of other European countries like France, the UK and Norway large regions with natural hard substrates are still present. Wrecks may contribute less to diversity of marine species in those countries.

But also in countries with rocky shores, the ecological importance of shipwrecks should not be neglected, as is illustrated by the case of the linear skeleton shrimp. Whereas coastal habitats experience a relatively high introduction rate of alien invasive species as a consequence of shipping activities (Gollash 2002), species communities on offshore habitats such as shipwrecks appear to experience less introductions of alien species. Offshore habitats may therefore stay free of alien species and form a refugium for pristine native species communities. Shipwrecks are arguably the best existing surrogate for natural hard substrates that have largely disappeared from the DCS (Lengkeek et al. 2011).

ACKNOWLEDGEMENTS

We thank Ben Stiefelhagen from Get Wet Maritiem, who initiated Duik de Noordzee schoon and the Dogger Bank expeditions in 2011 and 2012 and made several other dives possible. Furthermore we thank the crews of the Cdt.

Fourcault, the Aquila and Wilhelmina charter vessels. Without their professional support at all levels, the wreck dive expeditions would have been impossible. As the primary organising party we thank Duik de Noordzee schoon and acknowledge also the support of Get Wet Maritiem.
We also thank Godfried van Moorsel from Ecosub and Hans Waardenburg from Bureau Waardenburg for sharing their expert knowledge of North Sea ecology and species taxonomy and Wijnand Vlierhuis and Adriaan Gmelig Meyling from ANEMOON foundation for their observations and processing of data, respectively. For their financial support, we are very grateful to the Nationale Postcode Loterij, the Vereniging Kust & Zee (part of the Coastal & Marine Union EUCC), the North Sea Foundation (Stichting De Noordzee) and the Save our Seas Foundation.

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SAMENVATTING

Ecologische betekenis van scheepswrakken in de Noordzee

Dit artikel beschrijft observaties die gedaan zijn tijdens duikexpedities naar scheepswrakken in 2010-2012 om zo meer inzicht te krijgen in de ecologische waarde van scheepswrakken in de Nederlandse Noordzee. Hierbij werd geïllustreerd dat scheepswrakken hot spots zijn voor biodiversiteit. Het aantal soorten dat bekend is van zachte bodems van het gehele Nederlandse Continentale plat, is ongeveer gelijk aan het aantal soorten dat op wrakken is aangetroffen. Het oppervlak van het Nederlands grondgebied dat bestaat uit zandbodems is echter vele malen groter dan het bodemoppervlak waarop zich wrakken bevinden. Naast vele andere taxa, zijn grote en juveniele kabeljauwen, een inheemse spookkreeftje, de kliplipvis en de luipaardgrondel waargenomen op de wrakken. Het voorkomen van deze soorten, en hun afwezigheid in andere Noordzeehabitats, geeft aan dat scheepswrakken voor deze soorten noodzakelijke leefgebieden, kraamkamers en refugia vormen, die op andere plekken in Nederland niet meer of slechts sporadisch aanwezig zijn.

W. Lengkeek
Duik de Noordzee schoon
Bureau Waardenburg
Varkensmarkt 9
NL-4101 CK Culemborg, The Netherlands
W.Lengkeek@BuWa.nl
[Corresponding author]

J.W.P. Coolen
Duik de Noordzee schoon
IMARES Wageningen UR
P.O. box 167
1790 AD Den Burg – Texel, The Netherlands
Joop.Coolen@wur.nl

A. Gittenberger
Naturalis Biodiversity Center
Institute of Biology Leiden (IBL) & Institute of Environmental Sciences (CML), Leiden University
ANEMOON Foundation
GiMaRIS
J.H. Oortweg 21
NL-2333 CH Leiden, The Netherlands
Gittenberger@ GiMaRIS.com

N. Schrieken
ANEMOON Foundation
BiOrganized
Grenadiersweg 8
NL-3902 JC Veenendaal, The Netherlands
nielsschrieken@biorganized.com