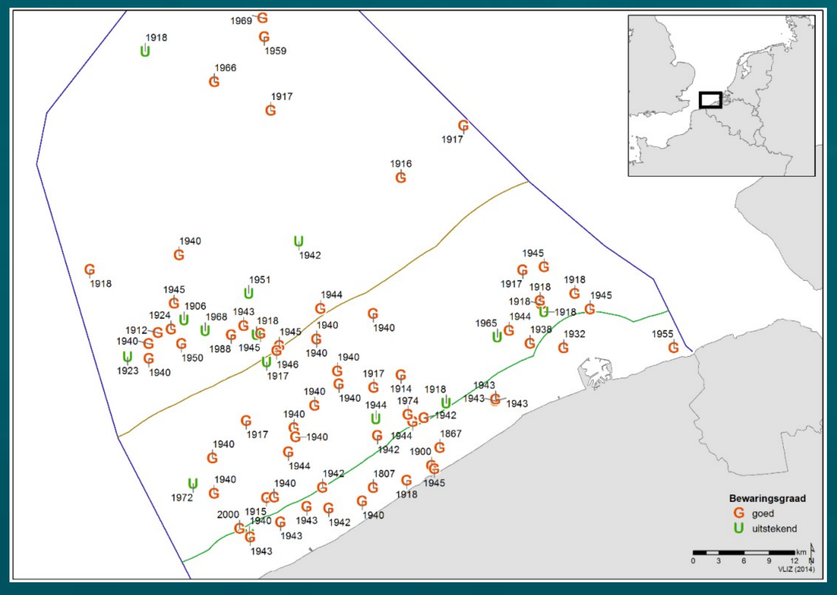
Analysis of corrosion rates on wreckage steel: a model exercise in the North Sea

Kris De Baere[(1)*], Sven Van Haelst[(2)], Raf Meskens[(3)], Remke Willemen[(3)], Deirdre Luyckx[(3)], Geert Potters[(3)].

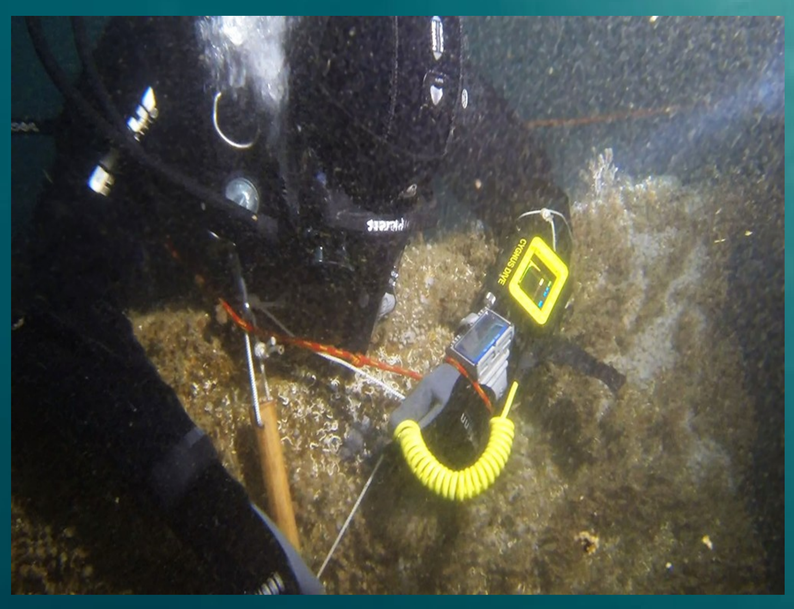
(1)* Corresponding author, Antwerp Maritime Academy, Antwerp, Belgium, kris.de.baere@hzs.be
(2) Flemish Maritime Institute, Brussels, Belgium, sven.van.haelst@vliz.be
(3) Antwerp Maritime Academy, Antwerp, Belgium, raf.meskens@hzs.be, remke.willemen@hzs.be, deirdre.luyckx.hzs.be, geert.potters@hzs.be

"The Belgian North Sea is harboring around three hundred shipwrecks. Some of them are of huge historical value. "The wrecks tell a dark story in our European history, but one that determines our society today. It is important to cherish and protect these memories." (P. De Backer - 2018)



Protecting under water wrecks is not evident. Starting point is the determination of the corrosion rate.
Methodology selected is the "weight loss method". Quantity of material lost was measured via plate thickness.
Double challenge:

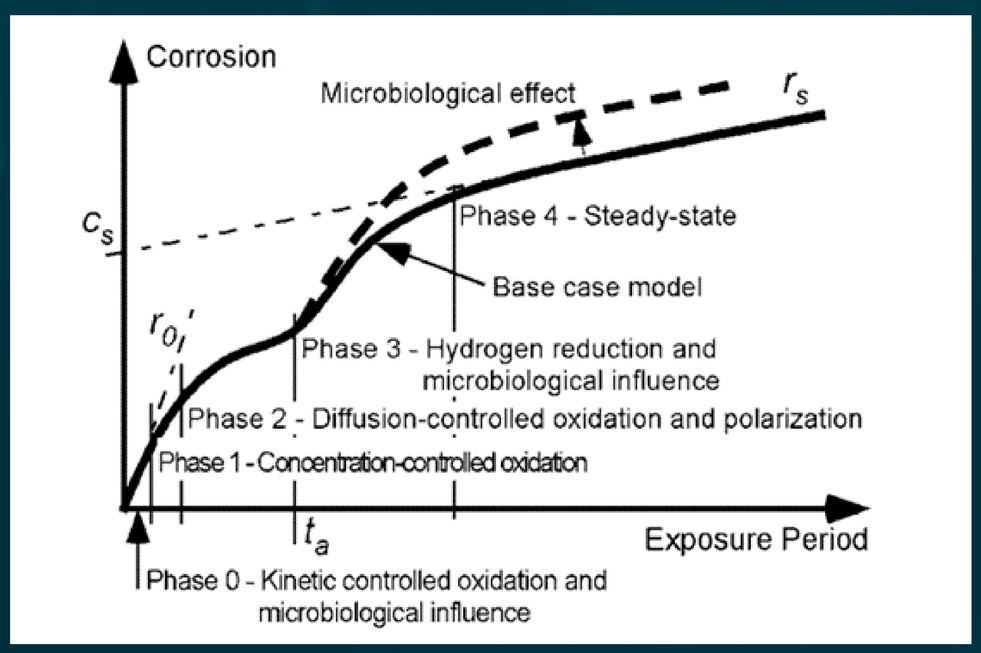
1. In situ measurements on the wrecks
2. Retrieval of the original construction data of the ships



At this moment we were able to measure 6 wrecks .

Name	Type of ship	Year Sunk	Thickness loss in mm per side
U11	U Boat	1914	2,63
UC II 61	U Boat	1917	1,64
UB III	U boat	1918	1,575
Birkenfels	Bulk Carrier	1966	1,26
Garden City	Cargo	1969	1,5
Sabrina II	Fishing Boat	1972	0,93

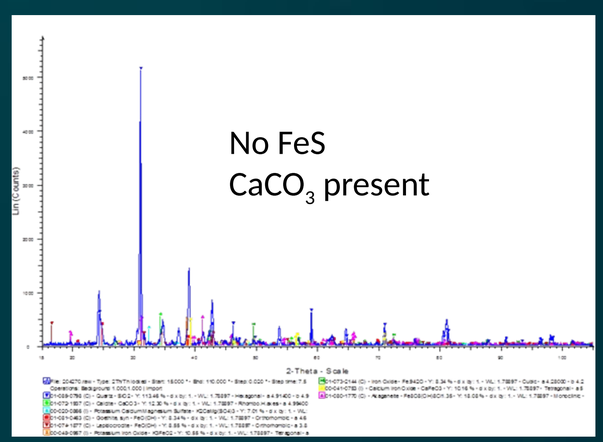
To bench our data to an existing and recognized model, we used the 4 phase model of Rob Melchers; New Castle University (Australia).

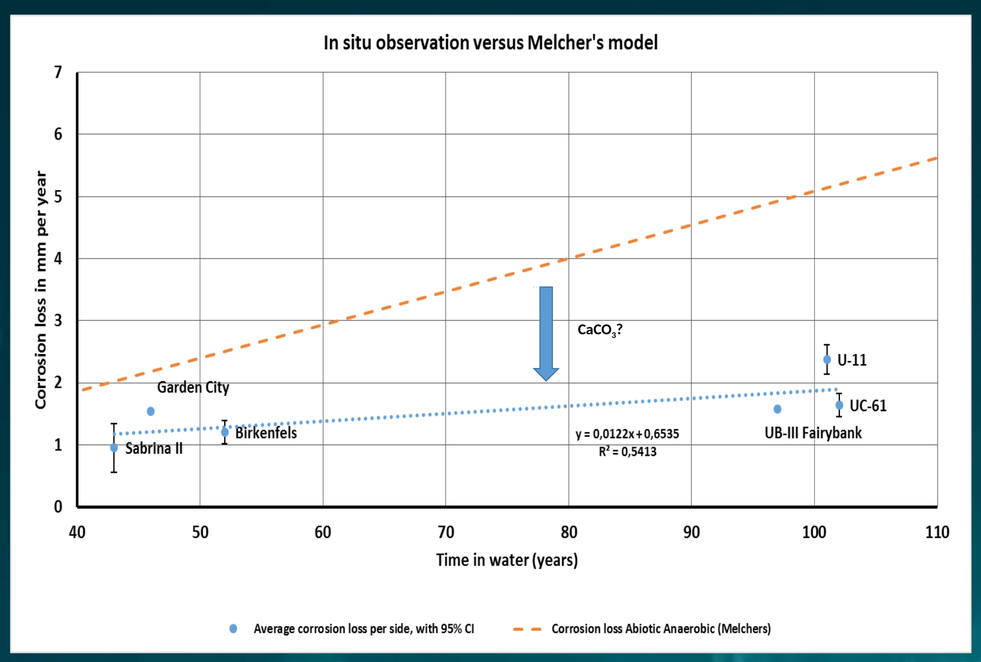


The relevant part of the Melchers model was used, namely phase 4 considering a seawater temperature of 12,5°C (VLIZ, 2018) and a DIN concentration of 0.3mgN/L (OSPAR, 2017).

XRD & DNA analysis were done on archeologic steel and no increase of the corrosion rate due to microbial activity could be established.

General corrosion seawater temperature 12.5°C		
t_a	6.61*exp(-0.088*T)	2,200277863
c_a	0.32*exp(-0.038*T)	0,199003218
r_0	0.076*exp(0.054*T)	0,149266506
r_a	0.066*exp(0.061*T)	0,141479488
c_s	0.141-(0.00133*T)	0,124375
r_s	0.039*exp(0.0254*T)	0,053573881





$$\text{Corrosion loss} = (c_s + (t-t_0)*r_s))*R_p$$

c_s = corrosion thickness at which the anaerobic activity becomes steady (mm)
t = total time since immersion (years)
t_0 = Time coating remains intact (years)
r_s = anaerobic steady corrosion rate (mm/y)
R_p = Ratio Corrosion loss with DIN/Corrosion loss without DIN

The abiotic anaerobic corrosion rate of steel in seawater according the Melcher's model is approx. 0,055mm/year. Our observations result in a corrosion rate approx. 3 times lower, being 0,015mm/year.

A possible explanation has been suggested by Rob Melchers.
The high concentration of carbonates in the North Sea water enhances the formation of $CaCO_3$ increases the pH and inhibits corrosion