Marine ecosystem engineers: a challenge for mine countermeasure

Sonia Papili [1,2,] Yves Dupont[3], Vera Van Lancker [2,4]

[1]Belgian Defence, Marinebasis Zeebrugge, Graaf Jansdijk 1, 8380 Zeebrugge, Belgium
[2]Ghent University, Department of Geology, Renard Centre of Marine Geology, Krijgslaan 281-S8, 9000, Gent Belgium.
[3]Belgian Defence, MR Naval Systems, Everestraat 1, 1140 Brussels, Belgium.
[4]Royal Belgian Institute of Natural Sciences. Operational Directorate Natural Environment, Vautierstraat 29, 1000 Brussels, Belgium.

Sonia Papili. Belgian Defence, Marinebasis Zeebrugge, Graaf Jansdijk 1, 8380 Zeebrugge, Belgium. E.Mail: sonia.papili@mil.be

Abstract: *Worldwide the marine environment is exploited increasingly and new challenges arise for communication, transportation, blue energy, seabed mining, aquaculture and coastal tourism. Meanwhile, the world of mine countermeasure is deeply changing as well, in terms of tactics, planning, sea monitoring, recognition and neutralization of threats. Human activities are increasingly regulated to steer exploitation towards most efficient, safe and sustainable ways. Safeguarding biodiversity is key and needs monitoring using most time- and cost-efficient ways. Biogenic reefs often form hotspots of biodiversity and therefore are important in the assessment of good environmental status of the marine environment (e.g.,Europe's Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC). As ecosystem engineers they modify, create or define habitats by altering the habitat's physical properties. From a military perspective, this poses challenges for mine countermeasure. First, biogenic reefs can hide man-made objects or even built on them. Secondly, they are visualized on sonar images showing mostly features with comparable dimensions to man-made targets; and lastly, their scattered spatial distribution makes monitoring and detection difficult.*

To provide assistance in discriminating seabed from man-made targets, a comprehensive table is constructed collecting the most recent and significant acoustic images showing the characteristic acoustic signature of a group of structural ecosystem engineers such as seagrass beds or tubeworms and evaluating the impact for mine countermeasure.

Key words: *Ecosystem engineers, mine countermeasure, remote sensing, biogenic reefs*

Methodology

Wever and Jenkins [1] provided evidence of biology affecting severely naval operations at sea, showing also that prediction capabilities can be mismatching if biological effects on the seafloor are not taken into account. Here, we demonstrate how ecosystem engineers modify the habitat and how those affect acoustic imagery. Results from a number of surveys are shown.
Sonar images were recorded using the Autonomous Unmanned Vehicle (AUV) REMUS 100 by Hydroid, equipped with a Side-Scan Sonar (SSS) using a very-high frequency of 900 kHz. Multibeam imagery (Kongsberg Simrad EM 1002 recording at frequency of 99kHz) was used as well.

Recordings with the REMUS 100 were performed in 2014 in Spain and in June 2016 in Belgian waters. The REMUS was programmed to fly 3 m above the seafloor at a velocity of 3 kn. Data were processed with the dedicated Hydroid software packages Sea Scan PC review and SSPC

data (Marine Sonic technology, Ltd. 2011). Recordings with the Multibeam EM 1002 data from 2007 were acquired with the research vessel A962 RV Belgica.
Main results are compiled into a comprehensive table in which different parameters are listed: used sonar and the frequency; type of ecosystem engineer; picture of the organisms; illustration of their spatial distribution and corresponding sonar images.

Ecosystem engineers

Not all ecosystem engineers are considered biogenic reefs *s.s.* [2], however any species modifying the seabed may affect acoustic imagery and be challenging in the context of mine countermeasures. Since seamines are found mostly in shallow waters (<50m), ecosystem engineers living in shallow waters were taking into consideration for this study. Three types of ecosystem engineers are presented: the polychaete *Lanice conchilega*, and the bivalve *Ensis directus*, widespread occurring in the North Sea, and the seagrass *Posidonia oceanica,* being of high value in the Mediterranean region.

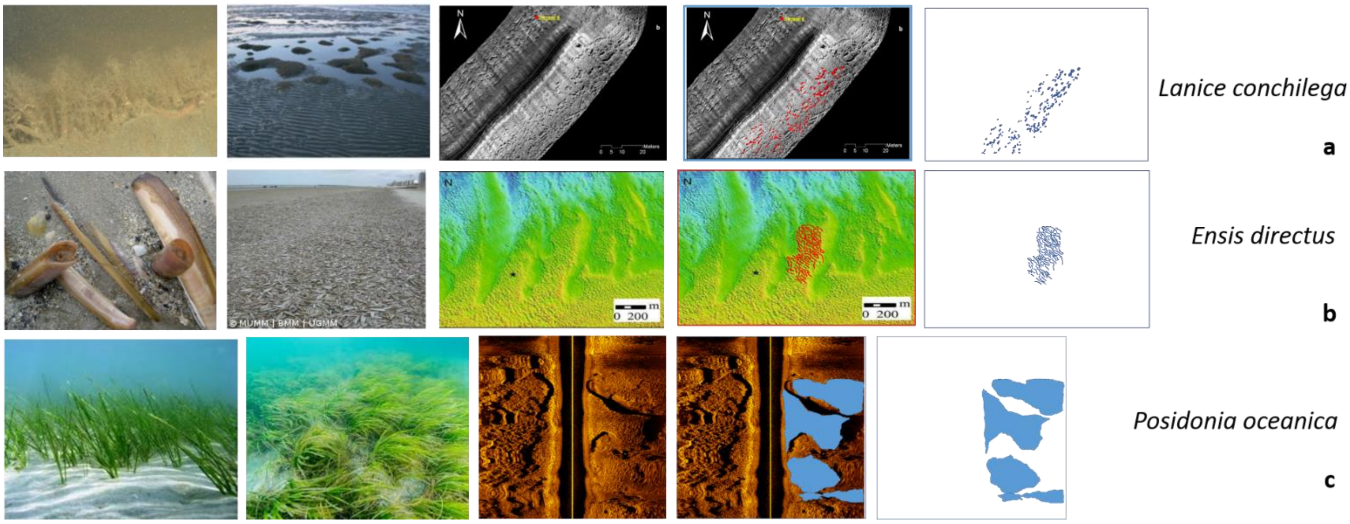
L. conchilega (Pallas, 1766) is a tubeworm typically occurring in the *Abra alba* community of the Belgian part of the North Sea (BPNS) and is strongly linked to shallow muddy to fine sands and medium sands, as well as to the deeper fine sands [3]. *L. conchilega* builds its tube with particles consisting of calcium carbonate grains (shell hash), up to 60-80 % of its volume [4]. The tube has a typical diameter of 0.5 cm and a length of up to 65 cm, although the tubes are mostly around 20 cm. The tubes protrude up to 4 cm above the sediment and have tentacles that ensure the feeding process [5]. *L. conchilega* is considered an ecosystem engineer since, when occurring in colonies, the tubes and tentacles are able to modify the near-bed hydrodynamic flow [6]. The reproduction peak of the species is in Spring, with two smaller peaks in Summer and Autumn [3].
E. directus (Conrad, 1843), also belongs to the *A. alba* community. Originating from North-Eastern America, the species started to invade the North Sea reaching the German Bight in the late 1970s and is spreading in Belgian waters since the 1980s [7]. Along the BPNS, stable adult populations were found in the vicinity of sandbanks, as also along the ebb tidal delta of the Westerschelde estuary [8]. The species tolerates a wide range of environmental conditions, but prefers slightly muddy fine sands in shallow waters where phyto-plankton is present [8]. The species can reach lengths of up to 16 cm and has a life stage of up to 5 years [8]. It has a high adaptability to environmental conditions, although it seems to avoid zones of higher sediment dynamics such as bedforms [9]. Its spawning period is in May and June [8].
Seagrass meadows [10] are formed from submersed marine angiosperms growing mainly on sandy or muddy substrates in shallow coastal and estuarine waters. Highly productive habitats are formed that also provide shelter to many organisms [10]. Apart from spawning grounds, they host larval and juvenile stages of many fish, mollusks and crustaceans [11,12], stabilizing bottom sediments and fixing carbon via photosynthesis [13]. An example is *Posidonia oceanicae* (Linnaeus, 1813) and is characteristic of the infralittoral zone of the Mediterranean in water depths from 0 to 40 meters. It can be found on soft or hard substrates and is tolerant to temperature variation and water movement, but are sensitive to desalination. They host mollusks, echinoderms and different species of fish.

Results

Some examples are given here of the acoustic signature of the ecosystem engineers described above. Their appearance is sketched from the sonar images allowing easy intercomparison. Depending on the type of organism and their lifecycles, the signature varies.

Table 1: Acoustic signature of ecosystem engineers derived by high frequency and very high frequency sonar images (b in [14]).

ID	Ecosystem engineer	Location	year	sonar type	frequency
a	*Lanice conchilega*	West diep gully (North Sea)	2016	SSS Remus 100 Kongsberg Hydroid	900 kHz
b	*Ensis directus*	Vlakte van de Raan (North Sea)	2007	MB EM1002 Kongsberg Simrad	95kHz
c	*Posidonia oceanica*	Spain (Mediterranean Sea)	2014	SSS Remus 100 Kongsberg Hydroid	900 kHz



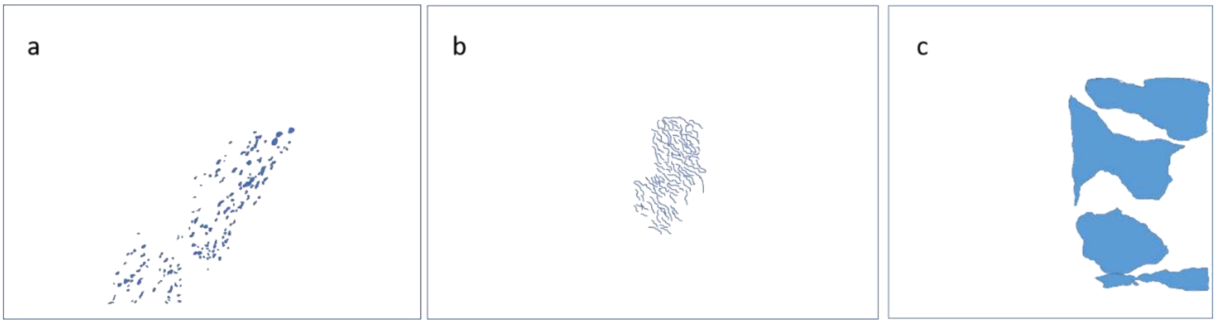


Fig.1: signatures of a) L.conchilega; b) E.directus; c) P.oceanica

The way dense colonies of tubeworms is ensonified is mostly described as rounded or elongated features and occurring in patches [15]. However, revisiting and discretizing, the signatures show that the spatial distribution of *L. conchilega* mostly follows the major axes of the main course of the autonomous vehicle aligned with the main tidal stream. This is not the case for colonies of *E. directus* that mainly develop against the main current direction. In both cases, the highly irregular shape and irregular distribution clearly sets them apart from regular bedforms, such as ripples.

Posidonia oceanica occupies large areas and the resulting features are large and compact. A preferential alignment is not evident.

For the search and detection of seamines this is highly valuable information.

Conclusion

Biological influence has been widely ignored in mine countermeasures, though it may impact considerably the sonar imagery and mask the presence of mines. However, there is large variability in the way organisms are imaged acoustically depending on a number of parameters that hitherto were not considered in a naval operational context: e.g., type of sediment, scale and shape of patchiness, linearity, spatial distribution, as well as seasonality.

During mine searches, it is important to have rapid assessment tools, including data bases with existing knowledge on the areas of interest, as well as the parameters influencing the signature as listed above. Additionally, it is envisioned to create a seafloor atlas illustrating ecosystem engineer's signatures on sonar images.

Approaching an era during which unmanned capabilities, automatic target detection and robotica will be used increasingly for mine countermeasures, it is crucial to supply to machines also environmental information with high level of accuracy and considering both physical and biological processes, as well as their interaction.

Acknowledgements

The authors thank Belgian Science Policy (BELSPO) for the use of the RV A962 Belgica and Flanders Marine Institute (VLIZ) for the use of RV Simon Stevin. The crew of both vessels is warmly thanked for their support. A special thanks goes to the VSW and REA Division of the NMCM department of the Belgian Navy for assistance during the remote sensing recordings. This paper contributes to the projects MRN015 funded by the Belgian Ministry of Defence, Royal Higher Institute for Defence. It also contributes to the project INDI67 (BELSPO, contract BR/143/A2/INDI67), and the SEACoP consortium in particular.

References

1. Wever, Th.F. & C.J. Jenkins, 2013. The Necessity of Entering Biological Effects on the Seafloor into Models and Doctrine for Navy Applications. Wehrtechnischer Bericht WTD71-0072/2013. 0-27.
2. Berke, S.K., 2010. Functional groups of ecosystem engineers: a proposed classification with comments on current issues. Oxford University Press on behalf of the Society for Integrative and Comparative Biology. Vol.50-2. 147-157.
3. Van Hoey G., 2006. Spatio-temporal variability within the macrobenthic Abra alba community, with the emphasis on the structuring role of Lanice conchilega. Ghent University: 0-187.
4. Fournier, J., C. Bonnot-Courtois, B. Caline, N. Desroy, S. Dubois, S. Etienne, L. Godet, J.B. Le Cam, M. Noernberg, & B Tessier, 2009. Calcium carbonate trapping by Sabellaria alveolata and Lanice conchilega and reef volume estimation: Preliminary results.

5. Callaway, R., 2003. Juveniles stick to adults: recruitment of the tube-dwelling polychaete Lanice conchilega (Pallas, 1766). Hydrobiologia 503:121– 130. doi:10.1023/B:HYDR.0000008494.20908.87
6. Rabaut, M., K. Guilini, G. Van Hoey, M. Vincx, & S. Degraer, 2007. A bioengineered soft-bottom environment: The impact of Lanice conchilega on the benthic species-specific densities and community structure. Estuarine Coastal and Shelf Science 75: 525-536
7. Kerckhof F. & E. Dumolin, 1987. Eerste vondsten van de Amerikaanse zwaardschede *Ensis directus* (Conrad, 1843) langs de Belgische kust. De Strandvlo 7(2): 51-52.
8. Houziaux J.-S., J. Craeymeersch, B. Merckx, F. Kerckhof, V. Van Lancker, W. Courtens, E. Stienen, J. Perdon, P.C. Goudswaard, G. Van Hoey, L. Vigin, K. Hostens, M. Vincx & S. Degraer 2012. 'EnSIS' - Ecosystem Sensitivity to Invasive Species. Final Report. Brussels: Belgian Science Policy Office. – Research Programme Science for a Sustainable Development:0-105.
9. Van Lancker, V., J.S. Houziaux, M. Baeye, D. Van den Eynde, M. Rabaut, K. Troost, T. Vermaas & T.A.G.P. van Dijk, 2013. Biogeomorphology in the field: bedforms and species, a mystic relationship. In: Van Lancker, V. & T. Garlan, (eds.). Conference Proceedings Marine and River Dune Dynamics, MARID IV, April 2013, Bruges, Belgium: 277-283.
10. Hamana M., Komatsu T., 2016. Real-Time classification of seagrass meadows on flat bottom with bathymetric data measured by a narrow multibeam sonar system. Remote sensing. Vol.8, 96. Doi: 10.3390/ rs8020096
11. Jackson, E.L.; Rowden, A.A.; Attrill, M.J.; Bossey, S.; Jones, M. The importance of seagrass beds as a habitat for fishery species. Oceanogr. Mar. Biol. 2001, 39, 269–304. 7.
12. Bertelli, C.M.; Unsworsth, R.K.F. Protecting the hand that feeds us: Seagrass (Zostera marina) serves as commercial juvenile fish habitat. Mar. Pollut. Bull. 2014, 83, 425–429.
13. Short, F.T.; Beth, P.; Livingstone, S.R.; Carpenter, K.E.; Salomão, B.; Bujang, J.S.; Calumpong, H.P.; Carruthers, T.J.B.; Coles, R.G.; Dennison, W.C.; et al. Extinction risk assessment of the world‘s seagrass species. Biol. Conserv. 2011, 144, 1961–1971.
14. Van Lancker, V. 2017. "Bedforms as Benthic Habitats: living on the edge, chaos, order and complexity." Atlas of Bedforms in the Western Mediterranean. Springer, Cham, 2017. 195-198.
15. Degraer S., G. Moerkerke, M. Rabaut, G.Van Hoey, I. Du Four , M. Vincx, J-P. Henriet & V. Van Lancker, 2008. Very-high resolution side-scan sonar mapping of biogenic reefs of the tube-worm Lanice conchilega. Remote Sensing Environ 112:3323–3328. doi:10.1016/j.rse.2007.12.012