Beheerseenheid van het Mathematisch Model van de Noordzee
MUMM | BMM | UGMM
Departement VI van het Koninklijk Belgisch Instituut voor Natuurwetenschappen

Universiteit Utrecht

NWO Top talent research proposal:

Biological and hydro-physical facilitation processes in the recovery of offshore gravel bed communities

Utrecht University – Master Thesis Environmental Biology
Anouschka A.C.M Kuijsters, 3220141
Examiner: Prof. dr. Henk Brinkhuis
Supervisor: Dr. Steven Degraer
28 February 2013

1. Basic details*[1]

1.1 Details of applicant:

Name + title: Anouschka A.C.M. Kuijsters, BSc. (F)
Contact address: xxxxxxxx
xxxxxxxx
Telephone: xxxxxxxx
E-mail: a.a.c.m.kuijsters@students.uu.nl

1.2 Details of intended supervisor:

Name + title: Dr. Steven Degraer
Contact address: BMM; Gulledelle 100,
B-1200 Brussels, BELGIUM
Telephone: +32(0)27732103
E-mail: s.degraer@mumm.ac.be

1.3 Host University representative (examiner):

Name + title: Prof. Dr. Henk Brinkhuis; Utrecht University
Contact address: Budapestlaan 4 (room Z308),
3584CD Utrecht, THE NETHERLANDS
Telephone: +31(0)302537691
E-mail: h.brinkhuis@uu.nl

*[1] Only publicly available information is published in order to respect privacy.

**This application serves as Master's thesis and will not be used for a PhD.*

2. Research proposal

2.1 Research field: Life sciences

2.2 Title of research proposal: “Biological and hydro-physical facilitation processes in the recovery of offshore gravel bed communities.”

2.3 Summary of research proposal:
Poorly understood ecological functions of marine 3d-structures and their associated processes will be clarified. We will focus on the importance of 3d-structures and water flow for colonization and succession. In addition, species general colonization capacity will be simulated.

2.4 Brief description of research proposal:

Introduction

Healthy gravel beds are considered to be benthic biodiversity hotspots[13,6], containing several ecosystem engineering species (EES)[14]. These species modify the abiotic environment e.g. by creating 3d-structures (biogenic reefs) which increase habitat complexity, resulting in diverse habitats used by a wide array of other species[2,5,6,13,14]. This way, gravel beds can serve as reservoir and function as a base to supply other areas[5,6,9,19].
However, since the last century many of the 3d-structures made by hard substrate forming fauna are either damaged or destroyed, mainly due to beam-trawling or species specific fishing (e.g. the European flat oyster was almost driven to extinction)[1,3,5,9,13]. With the loss of these structures, it is likely that fundamental ecological processes are lost as well: besides the extended biogenic structures, population size and biodiversity in general have severely declined on gravel beds since the introduction of beam-trawling[1,3]. Whether this is directly due to the loss of 3d-structures and suitable habitats, or indirectly, due to high fishing pressure, limited re-colonization or perhaps due to a combination of these, is still unclear. What we do know is that the importance of EES-structures has recently become emphasized[2].

Previous studies on settlement on (filamentous substrates on) the sea bottom have indicated that colonization can take place passively, by means of hydro-physical facilitation and actively, by means of biological facilitation. Passive facilitation indicates the physical environment regulating the number and types of organisms that can coexist in a community, whereas active facilitation can happen when the organisms in the environment modify it. Although it might differ per species, one does not necessarily exclude the other[2,4,7,10,16,18].
Although mutual bio-physical interactions are often aimed at the species’ own persistence, it might actually facilitate colonization by other species[2]. However, the applicability of this theory to (3d structures on) offshore gravel beds has, to our knowledge, not been researched yet. Therefore, this project will combine ecology and hydro-physiology to create a more accurate understanding of the ecological importance of marine 3d structures and their associated colonization processes.

**This application serves as Master’s thesis and will not be used for a PhD.*

Research questions
The main objective of this research project is to clarify the ecological processes that affect emerging gravel bed diversity and the functions of 3d structures, focusing on the colonization capacity of target species and the importance of 3d structures in the establishment of a marine biodiversity hotspot. Scientific results will be published (see 2.5 for working titles) and used to complement current knowledge of ecological processes and colonization mechanisms in marine gravel beds.

A. Which species can sustainably inhabit emerging gravel beds in the North Sea?
Although species diversity has decreased in the last century, Haelters *et al.*[9] stated that most of the species that were formerly present in gravel beds have not completely disappeared from the North Sea or surrounding waters. When a habitat is suitable and target species are still present, colonization by these species is theoretically possible[19]. Therefore, to clarify colonization potential, it is important to know: 1) which former inhabitants of gravel beds are currently present in the North Sea or adjacent waters and 2) what is the current colonization potential of these species with regards to habitat suitability?

B. What are the key processes behind early colonization of gravel beds?
When we have identified the colonization potential without fishing pressure, it is possible to go into more detail for key processes behind early colonization. Since each of the successional stages is linked to specific species, we cannot expect all target species to appear simultaneously. However, it might be expected that the appearance of some species attract other species directly or indirectly. Therefore we will clarify: 1) which species occupy early colonization stadia in gravel beds and 2) which ecological functions or successional mechanisms do they portray?
Although fishing pressure is not included in the previous research questions, it is and has been an actual threat for species richness and abundance since the last century [1,3,5,13]. To include the effects of (beam trawl) fishing that disturbs and moves rocks we will try to answer question 3) what are the differences between the early colonization phases of mobile (disturbed) and non mobile (non disturbed) gravel beds?

C. How can 3d-structures in gravel beds explain high biodiversity and density?
Ecosystem engineering species modify the abiotic environment via their behavior or physical structure[15]. By creating 3d-structures, they increase habitat complexity. This way a broader range of species can be supported by the habitat[11].
Borsje[2] indicated that epibenthic 3d-structures act as a physical barrier to the current, causing water velocity to decrease, resulting in particle traps. Whether this theory is also applicable on gravel beds is yet to be tested.
Nevertheless, since several marine species are deposited in the same way as passive particles[2,7,10], passive, hydrodynamic facilitation is expectedly involved in colonization. However, this does not necessarily lead to suitable habitat, indicating that active habitat selection plays a role[10] and might be influenced by species interaction.
To clarify whether complex 3d-structures attract more species than less complex structures and to analyze if and how biogenic and/or geogenic 3d-structures can

explain high biodiversity levels and species density in gravel beds, we will study the relative links to active and passive facilitation: 1) to what extent can high biodiversity in complex 3d-systems be explained by physical processes and 2) what effect does habitat complexity have on the species composition and density?

Methods

This project will consist of 3 parts: a review of existing literature, data and collections; flume tank and open water experiments; simulations with models that are based on past and present data. The research location is the Hinder area, which is part of the Belgian marine area and therefore directly accessible. This area has been extensively monitored and is often described as biodiversity rich[8,13]. The implementation of "ACTIEPLAN Zeehond"[17] in 2013, which encompasses inter alia the deposition of gravel and stones, ensures direct fieldwork opportunities.

A. Which species can sustainably inhabit emerging gravel beds in the North Sea?

1: Former common inhabitants of gravel beds will be selected from available data and historical collections. Among these we will select species from several succession phases of gravel beds among which fast growing, short lived, pioneer species like *Pomatoceros triqueter* and *Sabellaria spinulosa* (tube worms), slow growing long-lived EES like *Ostrea edulis and Alcyonium digitatum*, encrusting bryozoans like *Conopeum reticulum,* several hydroids, sea anemones, sponges and ascidians as well as echinoderms, introduced species like *Crepidula fornicata* and species that benefit from these habitats in terms of food, shelter and reproduction like fish (e.g. *Clupea harengus*) and marine mammals[6,13]. For the selected target species we will review existing literature[13], collections[8] and field reports by organizations such as OSPAR.

2: Because of high marine connectivity, even species that depend on the sea current for migration should be able to reach almost every gravel bed available in the North Sea. However, since species each have their own survival range of e.g. temperature, not all habitats will be suitable. To test habitat suitability of the Hinder area we will simulate whether the average monthly water temperatures, SPM concentrations and distance to shore match the ranges of our target species. In order to achieve this, available data from literature and collections will be used.

B. What are the key processes behind early colonization of gravel beds?

Because succession may be a very long process, it is not possible to study it entirely in detail during this project. Therefore we will focus on early colonization. We will analyze this in the Belgian windmill zone, where artificial gravel beds will be deposited for nature restoration purposes by the Belgian government. These gravel beds will remain undisturbed by fisheries.

1&2: Early colonization will be monitored in detail for 3 years. In year 1, sampling will be done in March, May, July and October. In year 2 and 3, sampling in May will be skipped. March and October respectively mark the periods before and after the recruitment season, whereas the period outside this period, linked to winter mortality, is less suitable for diving.

**This application serves as Master's thesis and will not be used for a PhD.*

To correct for spatial variability, 10 replicas will be collected in the artificial gravel beds by means of random sampling. We will identify species, ecological functions they fulfill regarding species interaction and successional mechanisms they portray: facilitation, inhibition or tolerance. Only if the variation between the samples proves to be high after analyzing three replicas, we will continue with the remaining samples until inter-sample variation (standard deviation) is acceptable.

3: To clarify the differences between the early colonization phases of mobile and less mobile gravel beds we will mark 3 sites of 3x3m in the windmill zone. Here we will simulate realistic disturbance by trawl fishing by turning over this 'mobile' gravel bed 1-3 times per year, after sampling. Like in methods section B1&2, 10 samples will be collected each time, within the inner 2x2m to minimize edge effects. At least three samples will be analyzed in detail.

C. How can 3d-structures in gravel beds explain high biodiversity and density?
Slow-growing structure forming fauna are expected to (re)establish on gravel beds without human intervention. However, because it would take a long time to let these structures develop naturally, we will simulate this succession phase with artificial 3d-structures varying in habitat complexity to simulate different stages of succession. Included are: stones with shells, branched structures or brushes, a combination of these and a substrate of oyster shells. Bare stones will be used as a control group.

1: The differences between the physical processes in the control group and 3d-structure groups will be tested experimentally in a flume facility (Leuven Univ., KUL) with the help of Prof. Dr. ir Jaak Monbaliu (engineering sciences, KUL). We will compare water velocity[2] and the relative physical concentration of propagules around the structure[10]. Each structure will be tested three times, by putting them in the middle of the flume for ten minutes and injecting passive particles into several locations of the flume pipe.

2. The effect of habitat complexity on species density will be tested in a flume experiment, as described in C1, by injecting passive particles (luminophores) of different volumes into the flume and analyze where they settle by means of an UV-camera. We will also conduct field experiments by putting the 3d-structures between the gravel beds of the windmill zone and monitor species diversity and density as described in B.

Innovation
The innovative aspects of this project are mainly linked to the combination of data and the interdisciplinary research strategy: linking ecology to hydrodynamics and engineering. We combine the knowledge of experts of these different research fields to enable us to cover a broad spectrum of all processes that are known to play a role in offshore marine gravel beds. That way, this project will render well-founded new knowledge on poorly known marine 3d-habitats and will clarify whether facilitation in these habitats proceeds actively by faunal activities, passively by hydro-physiological processes, or by a combination of these two.

**This application serves as Master's thesis and will not be used for a PhD.*

Relevance for science, technology or society

This project will be beneficial from socio-economical as well as scientific points of view. Not only will this research provide a better understanding of species interaction and ongoing processes in gravel beds, which are among the most diverse ecosystems in the North Sea, it will also help clarifying possibilities for sustainable restoration of the biodiversity and functions of these systems. By restoring these gravel beds they can again support a source population of fish, squid, lobster and other commercial food resources that have become scarce over the years. This will have positive effects for fisheries and reduces the depletion risk of valuable marine resources.

Literature references

1. Bergman, M.J.N., Duineveld, G.C.A., Lavaleye, M.S.S. (2005). Longterm closure of an area to fisheries at the Frisian front. Nioz-rapport 2005-6.
2. Borsje, B.W. (2012) Biogeomorphology of coastal seas – How benthic organisms, hydrodynamics and sediment dynamics shape tidal sand waves.
3. Buhs, F. and Reise, K. (1997). Epibenthic fauna dredged from tidal channels in the Wadden Sea of Schleswig-Holstein: spatial patterns and a long-term decline. Helgoland Marine Research 51:343-359.
4. Butman, C.A. and Grassle, J.P. (1992). Active habitat selection by *Capitella* sp. I larvae. I. Two-choice experiments in still water and flume flows. Journal of Marine Research 50:669-715.
5. Degraer, S., U. Braeckman, J. Haelters, K. Hostens, T. Jacques, F. Kerckhof, B. Merckx, M. Rabaut, E. Stienen, G. Van Hoey, V. Van Lancker & M. Vincx (2009). Studie betreffende het opstellen van een lijst van potentiële Habitatrichtlijngebieden in het Belgische deel van de Noordzee. Final report i.o.v. FSP Environment, Marine Environment. 93 pp.
6. Degraer, S., P. Adriaens, W. Courtens, J. Haelters, K. Hostens, T. Jacques, F. Kerckhof, E. Stienen, N. Vanermen & G. Van Hoey (2010). Bepalen van instandhoudingsdoelstellingen voor de beschermde soorten en habitats in het Belgisch deel van de Noordzee, in het bijzonder in beschermde mariene gebieden. Final report. FSP Environment, Marine Environment. 132 pp.
7. Fleeger, J.W., Yund, P.O., Sun, B.(1995). Active and passive processes associated with initial settlement and post-settlement dispersal of suspended meiobenthic copepods. Journal of Marine Res. 53:609-645.
8. Gilson, G. (1900). Explorations de la Mer sure les côtes de la Belgiques en 1899. Mémoires du Musée Royal d'Histoire Naturelle de Belgique, I, Bruxelles, 81pp. (Incl. physical collection at RBINS)
9. Haelters, J.; Kerckhof, F.; Houziaux, J.-S. (2007). De aanduiding van mariene beschermde gebieden in de Belgische Noordzee : een mogelijke uitvoering van OSPAR aanbeveling 2003/3 door België. Koninklijk Belgisch Instituut voor Natuurwetenschappen: Brussel. 46 pp..
10. Harvey, M. and Bourget, E. (1995). Experimental evidence of passive accumulation of marine bivalve larvae on filamentous epibenthic structures. Limnology and Oceanography 40:94-104.
11. Hauser, A., Attril, M.J., Cotton, P.A. (2006). Effects of habitat complexity on the diversity and abundance of macrofauna colonizing artificial kelp holdfasts. Marine Ecology Progress Series 325:93-100.
12. Houziaux J.-S., Degrendele K., Norro A., Mallefet J., Kerckhof F. and Roche M. (2007). Gravel fields of the Western Belgian border, southern bight of the North Sea: a multidisciplinary approach to habitat characterization and mapping. Proceedings of the conference "UAM2007 - Underwater Acoustic Measurements: Technologies and Results", Heraklion, Crete:847-854.
13. Houziaux, J.-S., Kerckhof, F., Degrendele, K., Roche, M. & Norro A. (2008). "The Hinder banks : yet an important region for the Belgian marine biodiversity?" ('HINDERS'). Belgian Science Policy Office, Final report. 123 pp. + 131 pp. annexes.
14. Jones, C.G., Lawton, J.H., Shachak, M. (1994). Organisms as ecosystem engineers. Oikos 69:373-386.
15. Jones, C.G., Lawton, J.H., Shachak, M. (1997). Positive and negative effects of organisms as physical ecosystem engineers. Ecology 78:1946-1957.
16. Kern, J.C., Taghon, G.L. (1986). Can passive recruitment explain harpacticoid copepod distributions in relation to epibenthic structure? Journal of Experimental Marine Biology and Ecology 101:1-23.
17. Ministerie van de Noordzee (2012). Actieplan ZEEHOND: van defensief naar offensief milieubeleid in de Noordzee.
18. Pawlik, J.R., Butman, C.A., Starczak, V.R. (1991). Hydrodynamic facilitation of gregarious settlement of a reef-building tube worm. Science 251:421-424.
19. Townsend, C.R. (1989). The patch dynamics concept of stream community ecology. Journal of the North American Benthological Society 8-36-50.

Total number of words: 1918 (excl. references).

**This application serves as Master's thesis and will not be used for a PhD.*

2.5 Plan of work

Year	Research activities
2013 **start Sep.**	Preparation of experiments (B&C); Literature review (A & general)
2014	Simulations (A); flume experiments (C); sampling (B); paper writing. <u>Output:</u> A1 - Working document: *"The current presence of former gravel-bed inhabiting species."* A2 - Scientific paper: *"Colonization potential of former gravel bed inhabiting species in the North Sea."*
2015	Flume experiments (C); result analysis; publication C1&C2; sampling (B); paper writing. <u>Output:</u> C1 - Scientific paper: *"Hydro-physiological processes as driver of species richness and density in complex 3d-systems."* C2 - Scientific paper: *"The role of habitat complexity in species composition and density in marine 3d-systems."*
2016	Sampling (B); result analysis; paper writing. <u>Output:</u> B1+2 - Scientific paper: *"Ecological functions of early colonizing species in offshore gravel beds of the North Sea."* B3 - Scientific paper: *"Differences in early colonization phases of mobile and non-mobile gravel beds in the North Sea."*
2017 **until Aug.**	Final dissertation

**This application serves as Master's thesis and will not be used for a PhD.*

3. Cost estimates

3.1 Budget

	Sep.2013	2014	2015	2016	Aug.2017	Total
Staff[1]	*(€1.520)*	*(€7.600)*	*(€6.080)*	*(€5.700)*	*(€3.040)*	*(€23.940)*
Applicant[2]	€9.400	€28.200	€28.200	€28.200	€18.800	€112.800
Non staff[3]	-	-	-	-	-	-
Bench fee[4]	€1.500	€1.000	€1.000	€1.000	€500	€5.000
Equipment[5]	€2.000	-	-	-	-	€2.000
Consumables[6]	€2.500	€1000	-	-	-	€3.500
Travel[7]	€833	€2.500	€2.500	€2.500	€1.667	€10.000
Other[8]	€2.167	€2.000	€2.000	€2.000	€1.333	€9.500
Total	€18.400	€34.700	€33.700	€33.700	€22.300	€142.800

Specification of requested funds:
1. Guidance by MUMM and expert participation will be in kind. Experts will be involved approximately 15 days in total (6 days in year 1/2, 5 days in year 2/3 and 4 days in year 3/4 at a rate of ~€380/day, a memorandum.) MUMM will provide guidance at the same fee, approximately 12 days per year, a memorandum.
2. The graduate school of life sciences (UU) website states that the applicant receives €2.062-2.638 per month, increasing per year. This equals an average of €2.350 per month, which is used for these calculations.
3. Boatman and diving buddy will be arranged through MUMM (volunteers).
4. The bench fee is standard fee of €5.000 in total. This is spread over the project with the biggest part in the first year, to purchase materials.
5. Diving gear will be bought in year 1. Renting is possible (except for dry-suit), but evenly or more expensive. Flume tank, flow velocity meters, UV-camera and analyzing software will be provided by KUL, free of charge. Underwater camera will be borrowed from MUMM.
6. Includes local transportation. Ship time is provided by the Flemish and Belgian Federal government (in kind), whereas artificial gravel banks are provided by "plan ZEEHOND", an initiative of the Belgian Ministry of the North Sea. Sampling material, rocks and 3d- structures (~20x) are estimated at €1.000. Gabions with oyster shells are estimated at €1.500. Luminophores are estimated at €1000 (€25-50 per kilo).
7. Transportation and participation fees of symposia and training in Europe. Included are 8 trainings and 12 symposia (estimated at ~€500 on average).
8. Includes laptop incl. software purchased in year 1 (~€1.500) and unforeseen costs (€2.000 per year).

3.2 Costs exceeding the grant

The maximum amount of the grant is 180 k€. Costs exceeding the maximum grant must be met by the university. University guarantees to meet additional costs and to provide support services and supervision. No, extra costs will be met by the MUMM in context of the Habitat Directive objectives.

3.3 Other Grants

Have any other grants for this project or for the applicant been requested either from NWO or from any other institution? No.

**This application serves as Master's thesis and will not be used for a PhD.*

4. Curriculum Vitae*[2]

*[2] My C.V. is not publicly accessible and therefore not included in this (open access) document. For more information please contact: a.a.c.m.kuijsters@students.uu.nl .

This application serves as Master's thesis and will not be used for a PhD.