Enhancing marine coastal biodiversity in Normandy: towards a new species signalling network using Artificial Structures

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IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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Enhancing marine coastal biodiversity in Normandy: towards a new species signalling network using Artificial Structures

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Abstract. Non-Indigenous Species (NIS) are a threat to native biodiversity and ecosystem services. The European seas are known to be the recipient of several hundreds of NIS due two main origins: shipping and aquaculture. They are the focus of Descriptor 2 of good environmental status in the Marine Strategy Framework Directive. 153 NNS had been recorded along the Normandy coast in 2018. Marinas are priority sites for monitoring, being 'hotspots' for the NIS occurrence. The aim of the ENBIMANOR project was to study and compare the composition and the hard-bottom macrofauna including the NIS prevalence in marinas along the Normandy coast (from Granville to Dieppe-Le Tréport) focusing primarily on mobile and benthic invertebrates. A total of 19 marinas were surveyed during two years (2018-2020). At each harbour, nine settlements panels (acting as artificial reef) were immerged at a depth of 1.50 m. Every quarter, at each site, a settlement panel was replaced and the species colonising the panel were identified. The analysis revealed higher taxonomic richness in marinas open to the sea or with high salinity than in closed marinas or with low salinity. Results highlighted that each marina has its own species composition. This survey identified more than one hundred taxa, including known NIS species such as the amphipod *Monocorophium acherusicum* and *M. sextonae,* the ascidians *Perophora japonica* and *Stylea clava,* and detect four new NIS for the Normandy waters (*Aoroides longimerus, A. curvipes, Paranthura japonica* and *Ianiropsis serricaudis).*Our study shows the need to continue the census of NIS and to evaluate their impacts on the artificial hard-bottom structures in marine coastal ecosystem on two major zones: the intertidal zone and the marina/harbours waters.

1. Introduction

Intentional or unintentional species introductions by human activities to regions outside their native ranges have been on-going for thousands of years [1]. However, these ecosystem invasions by Non-Indigenous Species (NIS) are considered nowadays as one of the greatest threats to biodiversity world-wide [2,3]. NIS introductions into coastal zones have been accelerated thorough the world in recent decades mainly due to increased human activities such as shipping, aquaculture, maritime traffic and tourism [4]. This increase of NIS introduction occurring in the context of global climate change leads to modifications in the ecosystem structure and function with potential repercussions on their ability to provide goods and services to humans [2]. In fact, NIS presents a wide range of threats to native ecosystems, and can be responsible for the decline of native species by competition and predation, and thus can lead to a loss of biodiversity [5]. Moreover, NIS can also cause direct economic impacts on human activities structure and aquaculture. Invasive species can also cause disappearance of the original communities. A famous example is the invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea, which led to a collapse of pelagic fisheries. Finally, it is worth to note that in the marine environment, these introductions are most of the time irreversible. Long term dataset analyses on NIS can provide insights into past and future trends for conservation purposes [6]. However, such monitoring surveys are relatively rare [6]. In this context, the ENBIMANOR project (ENhancing MArine, coastal BIodiversity in NORmandy: towards a new species signalling network) aims to understand the evolution in biodiversity of the Normandy coastline and marinas. This on-going project analyses the fixed hard-substrate fauna present in marinas and will test the hypothesis that the ports of Normandy with high numbers of cross-Channel and international traffic (Cherbourg, Ouistreham, Le Havre et Dieppe) are the main pathway of introduction of non-indigenous (but rarely invasive) species.

2. Materials and Methods

2.1 Experimental designs

We selected 19 marinas with floating pontoons located along the 640 km long coastline of Normandy, from Granville to Le Tréport (Figure 1). These marinas were representative of a range of characteristics (open to the sea or closed, fully marine or under freshwater (estuarine) influence). The species settlement dynamics were investigated in these 19 marinas. In each marina, nine panels (25 cm x 25 cm; 0.065 m²; Figure 1) were immersed at 1.5 m depth under a pontoon. Every quarter, in each marina, plates were removed and analysed after 3, 6, 9, 12, 15, 18 and 24 months, in order to view the entire colonisation sequence. The retrieved specimens of each plate were preserved in alcohol solution and taken to the laboratory for identification. Then organisms were sorted, identified and counted using a binocular microscope and stored in alcohol. In addition, each month in each marina, a CTD probe was used to monitor standard physico-chemical parameters (temperature, salinity, turbidity and concentration of dissolved oxygen). In this study, we only present the main results corresponding to the monitoring period of 15 months. The physico-chemical parameters were presented for 18 marinas during the 15 months (Saint Vaast la Hougue was equipped only after 12 months). For the biological analysis, the site of Le Tréport was excluded (absence of fauna), thus, the analyses were made on 17 marinas.

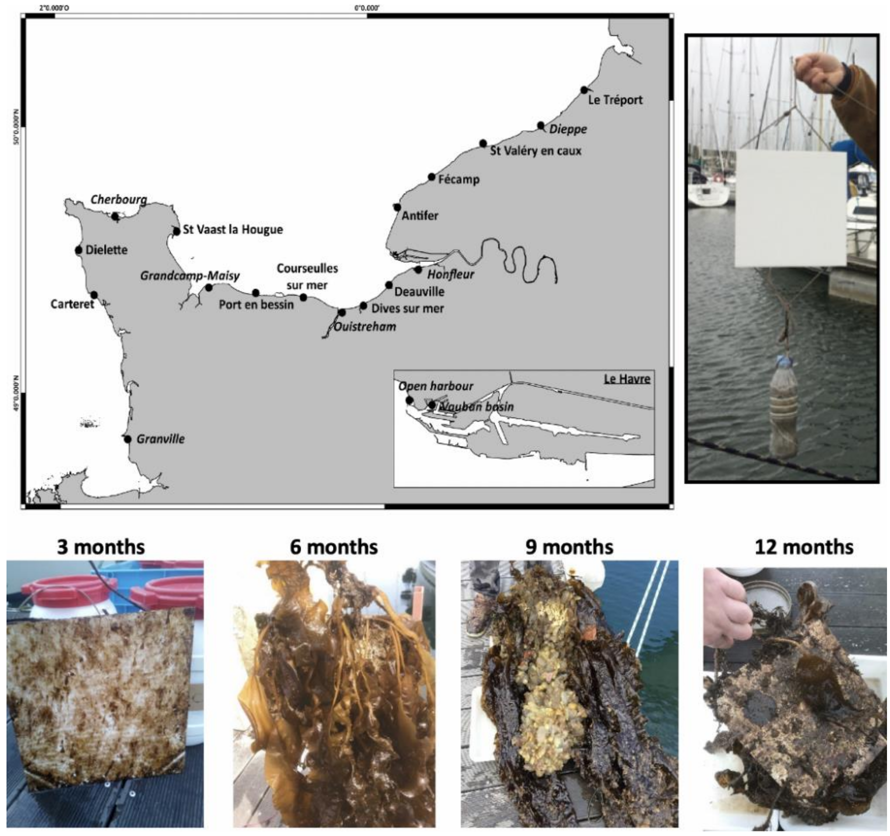

Figure 1. Location of the 19 marinas selected and photography's from Cherbourg from 3 to 12 months of plate colonisation.

2.2 Data analysis

First, the typology of the 18 marinas was investigated using the multivariate analysis, a Hierarchical Ascendant Classification (HAC) was created by means of group-average linking using the Bray-Curtis similarity measure.

Then, species names were checked with World Register of Marine Species (WORMS, http://www.marinespecies.org) on June 2019. The community structure analysis was based on the taxonomic richness, the Shannon-Wiener diversity index H′ using $\log_2$ base and the Pielou evenness index J′. Both indices were calculated for plates in each marina, for a total of 17 marina.

The spatial structure of the benthic community of the 17 marinas was investigated using the multivariate analysis method of Clarke and Warwick (1994) with the PRIMER-6 software package (Plymouth Routines In Multivariate Ecological Research). Data analyses were performed by using non-metric multidimensional scaling ordination (nMDS), and a Hierarchical Ascendant Classification (HAC) was created by means of group-average linking using the Bray-Curtis similarity measure. $\text{Log}_{10}(X+1)$-transformed data were used to down-weight the effect of the highly abundant species

3. Results

3.1 *Typology of the marinas*

Physico-chemical parameters (temperature, salinity, turbidity and concentration of dissolved oxygen) were similar in 75 % of the 18 marinas (excluding Saint-Vast-La-Hougue). A cluster analysis separates the marinas into two main groups (Figure 2). In addition, the first group "A" can be further divided into three sub-group: The sub-group "A1" corresponds to the marina located in the Seine Maritime, the sub-group "A2" comprises the marinas located along the Northwest coast of the Cotentin while the sub-group "A3" corresponds to the marinas located along the Calvados coast. The second group "B" corresponds to three following marinas: Tréport, Honfleur and Ouistreham marina.

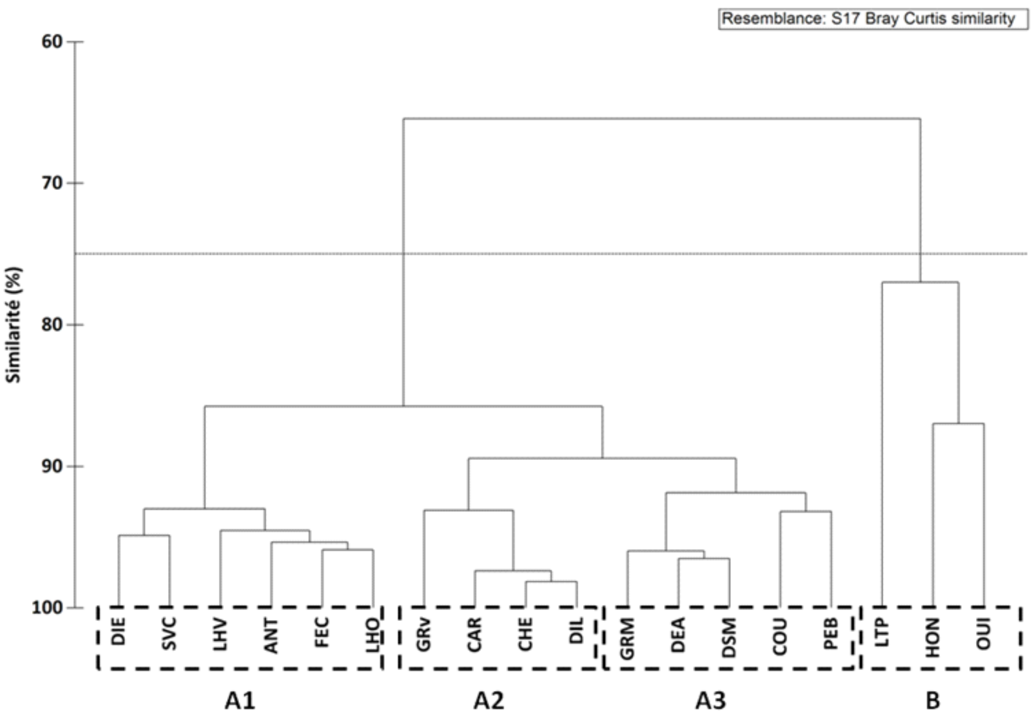

Figure 2. Cluster dendrogram showing distribution of the 18 marinas according to the physico chemical parameters.

Results also showed that the sub-group “A1” had the lowest average temperature with 10.88°C. The group “B” had the highest average concentration of dissolved oxygen (7.35 $mL.L^{-1}$) and the lowest average salinity (7.016) while the highest salinity values were recorded in the marinas belonging to the sub-group “A2”. The highest mean turbidity was found in the sub-group “A3”, with 6.88 (Table 1).

Table 1. Physico-chemical parameters (minimum, average and peaks) of the three subgroups (A1, A2, A3) and the group B

	A1	A2	A3	B
Temperature (°C)	6.7-**10.9**-17.0	7.2-**11.4**-16.0	6.7-**11.4**-16.7	6.8-**11.5**-18.1
Dissolved Oxygen (mL/L)	5.6-**6.7**-7.9	5.6-**6.2**-6.8	5.6-**6.4**-7.8	6.1-**7.3**-8.4
Turbidity (NTU)	0.4-**3.9**-12.2	0.5-**3.3**-10.3	1.4-**6.9**-24.2	0.8-**3.5**-8.0
Salinity	0.8-**23.9**-32.2	32.1-**34.1**-34.9	9.2-**28.8**-32.7	0.5-**7.0**-14.8

3.2 Biological analyses

A total of 141 taxa was recorded during the 15 months of survey of 17 marinas (excluding Saint-Vaast-La-Hougue and Le Tréport). Among these taxa, the macrofauna is dominated by arthropoda (75 taxa), following by annelida (31 taxa) and mollusca (15 taxa). Concerning the Shannon-Weaver diversity index (H’), a significant difference is observed between the early stages of settlement (three and six months) and the later stages of the study (12 and 15 months) with highest values in the later stages (Table 2). The taxonomic richness increases during the first year of immersion and a new annual cycle begins the next year. H’ shows the same pattern. About abundances and Piélou index, results showed that time did not affect them. There was no difference between sites with taxonomic richness, abundance, Shannon or Piélou index. A biological succession is observed over time: a first assemblage mainly dominated by barnacle’s pioneer taxa, which build new surfaces, new structures, and allowed the colonization by some other taxa. Out of the 141 taxa, 20 NIS were recorded (14.2%). It was worth to note that NISs were recorded in the 17 marinas. However out of the 20 NISs, 12 were recorded in marinas presenting a high traffic maritime (Cherbourg, Dielette, and the two Le Havre harbours).

Finally, considering only the abundance found on the panels corresponding to one year of immersion, results showed that for a similarity of 40%, we detected spatio-temporal patterns; the dendrogram separated the marinas into eight groups (Figure 3). The group « e » corresponds to marinas with high maritime traffic related to scallop fisheries. The group « f » corresponds mainly to marinas located along the Seine Maritime coasts while the group «h » corresponds to marinas located under freshwater influence. The other groups are isolated from any clustering, indicating different communities between marinas and harbours.

Table 2. Main biological characteristics of the 17 marinas. Taxonomic richness (TR), total number of species over 0.0625m² x 2. Ab (Abundance), total number of organisms over 0.0625m² x 2. H'(log2), Shannon Index. J', Pielou index. Colour-coded according to WFD (Water Framework Directive) definition of good ecological status; blue: high ecological status, green: good ecological status, yellow: moderate ecological status, orange: poor ecological status; red: bad ecological status.

Marinas	Panel	TR	Ab	H'(log2)	J'	Marinas	Panel	TR	Ab	H'(log2)	J'
ANT	P1	7	7861	0,1029	3,67E-02	GRM	P1	4	13	1,614	0,8072
	P2	14	5040	1,821	0,4783		P2	4	122	1,581	0,7906
	P3	22	4692	2,639	0,5918		P3	9	26	2,854	0,9002
	P4	24	1093	2,534	0,5526		P4	14	3143	0,522	0,1371
	P5	21	1844	2,503	0,5698		P5	15	1308	2,069	0,5296
CAR	P1	6	106	1,244	0,4812	GRV	P1	5	13	2,295	0,9886
	P2	9	587	0,7115	0,2244		P2	11	359	2,454	0,7092
	P3	17	292	2,075	0,5077		P3	14	185	3,171	0,8329
	P4	12	2288	0,8064	0,225		P4	28	321	3,645	0,7582
	P5	8	27	2,773	0,9243		P5	17	123	2,694	0,659
CHE	P1	8	26	2,637	0,879	HON	P1	2	17	0,3228	0,3228
	P2	12	558	2,484	0,6928		P2	3	20	0,9219	0,5817
	P3	19	4661	1,759	0,4141		P3	10	4083	0,7131	0,2147
	P4	21	1867	1,796	0,409		P4	16	12097	2,32	0,58
	P5	17	1859	1,45	0,3547		P5	12	1314	2,387	0,6658
COU	P1	6	41	1,973	0,7634	LHO	P1	1	2	0	****
	P2	2	196	0,1142	0,1142		P2	11	359	1,309	0,3783
	P3	10	255	1,901	0,5721		P3	26	4881	1,697	0,3611
	P4	18	1094	2,609	0,6256		P4	28	1126	2,783	0,5788
	P5	10	1096	1,581	0,476		P5	14	181	2,879	0,756
DEA	P1	3	18	0,6144	0,3876	LHV	P1	7	20	2,433	0,8667
	P2	4	13234	3,43E-03	1,72E-03		P2	10	1337	1,412	0,4251
	P3	11	1905	1,63	0,4713		P3	25	9831	1,962	0,4225
	P4	15	6173	2,075	0,5311		P4	17	1157	2,708	0,6625
	P5	19	2182	2,499	0,5883		P5	10	298	0,9508	0,2862
DIE	P1	3	100	0,4457	0,2812	OUI	P1	4	43	0,678	0,339
	P2	9	915	1,247	0,3933		P2	4	8	1,75	0,875
	P3	16	3535	2,332	0,583		P3	11	17454	0,2018	5,83E-02
	P4	23	2913	2,348	0,5191		P4	12	16624	1,263	0,3522
	P5	12	3297	0,6244	0,1742		P5	9	534	2,28	0,7193
DIL	P1	6	118	0,9989	0,3864	PEB	P1	4	40	1,794	0,8972
	P2	14	942	1,198	0,3148		P2	7	11268	7,25E-02	2,58E-02
	P3	14	1415	1,847	0,485		P3	9	357	2,384	0,752
	P4	22	6808	1,713	0,3842		P4	22	2022	2,692	0,6036
	P5	10	4046	1,516	0,4563		P5	12	416	2,412	0,6727
DSM	P1	6	9	2,503	0,9684	SVC	P1	9	325	0,6289	0,1984
	P2	9	22721	7,72E-02	2,43E-02		P2	5	306	1,303	0,5614
	P3	7	3014	0,3203	0,1141		P3	12	807	1,71	0,477
	P4	17	2458	1,667	0,4078		P4	17	431	2,929	0,7165
	P5	7	1563	1,282	0,4568		P5	20	1320	2,604	0,6024
FEC	P1	6	654	0,253	9,79E-02						
	P2	8	977	0,8901	0,2967						
	P3	25	3311	1,936	0,417						
	P4	27	3417	1,94	0,408						

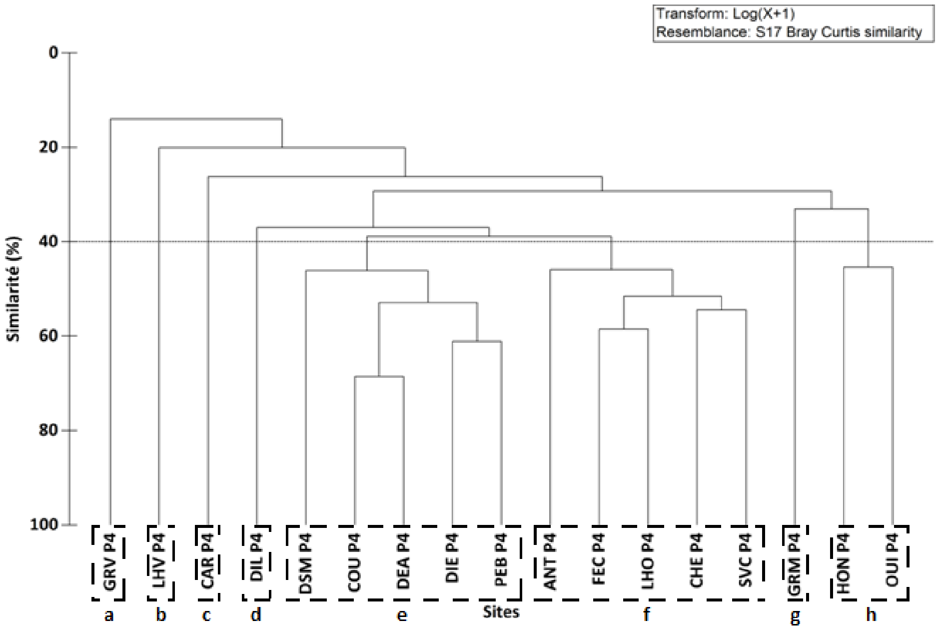

Figure 3. Cluster dendrogram showing distribution of the 17 marinas to the abundances (mean abundance after 12 months of colonisation corresponding to P4) according to the Bray-Curtis similarity after Log(x + 1) transformation of the abundance.

4. Discussion

Analyses from the physico-chemical data permitted to characterize the marinas in different groups. This typology was based on the following criteria: the number of moorings in each marina, open to the sea or closed, fully marine or under freshwater influence and the traffic maritime. According to this typology, the marinas were gathered in four groups: a group comprised of the marinas located along the west coast of the Cotentin, a group comprised of the marinas located along the Calvados coasts, a group comprised of the marinas located along the Seine maritime coasts, and a group of marina strongly influenced freshwater inflows. The analyses also highlighted higher taxonomic richness in marinas open to the sea or with high salinity than confined and / or with low salinity. It is also important to note that each port has its own unique fauna.

This survey allowed to identify more than one hundred taxa, including known NIS species such as the amphipod *Monocorophium acherusicum*, *M. sextonae*, the ascidians *Stylea clava*, the polychaete *Ficopomatus enigmaticus* and detect several new NIS for the Normandy waters (*Aoroides longimerus, A. curvipes, Paranthura japonica* and *Ianiropsis serricaudis)*. For instance, high abundance of *Corophium* were observed in the 17 marinas with several thousands of individuals collected and could reach over 6,500 individuals over 0.0625m² x 2. All these species originate from the north-western Pacific in Chinese and Japanese waters.

Two pathways of NIS introduction in Normandy have been proposed. The first is maritime transport; in particular Le Havre and Cherbourg. In fact, several studies pointed out that the Havre Harbor is the first place for the record of NIS in the English Channel [5]. The second pathway is aquaculture, mainly of the Japanese oyster *Crassostrea gigas* (Thunberg, 1793) and its transfer between the Atlantic and English Channel oyster centers of production [5]. Our study revealed that NISs were found in the 17 marinas and not only in the marina with high traffic maritime. This result is in line with the hypothesis of Alfonso et al. 2020 [7]; Ros et al. 2013 [8]; Chainho et al. 2015 [9]; Martinez-Laiz et al. 2019 [10] who stated that Recreational marinas are points of entry for potential colonizers and can act as steppingstones or corridors for the spread of these species. NISs that seems to be able to disperse outside the marinas have planktonic larval stages and higher environmental tolerance, which seems to have contributed to the successful spread.

Our experiment showed the efficiency of such panels to be colonized by several marine species including NIS. In addition, the results of the present study highlighted that the colonization of such panels deployed in marina is efficient to provide an inventory of sessile and motile invertebrates living in the marinas. Finally, the results also emphasized the importance of monitoring NIS occurrence in marinas, in order to detect the arrival of new potential invaders and to prevent its dispersal to sensitive ecosystems.

5. Acknowledgements

This study forms part of the REGENI (Réalisation d'un Guide des Espèces Non-Indigènes) and ENBIMANOR (ENrichissement de la BIodiversité MARine en NORmandie) projects financed by the AESN (Agence de l'Eau Seine Normandie).

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