Does wastewater treatment plant discharges drive rocky subtidal community shifts? A case study

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INTRODUCTION

Contamination by wastewater discharges is one of the main anthropogenic stressor affecting rocky shore assemblages around the world. This study focused on the response of rocky subtidal benthic communities to wastewater treatment plant (WWTP) discharges in a very exposed location on the Basque coast (Southeastern Bay of Biscay). To meet the requirements of European Directives (Water Framework Directive and Marine Strategy Framework Directive), both benthic macroalgae and macrofauna were considered. These both biological elements play a key role in the assessment of the conservation status and functional role of the ecosystem.

General hypothesis: If WWTP treatment would be efficient, structural parameters of communities, functional diversity and current ecological quality indices between impacted and control locations should be similar.

MATERIALS AND METHODS

WWTP: the most important wastewater discharge in a subtidal environment along the French rocky Basque coast (inhabitant equivalent: 40000 ; main treatment: biofiltration).

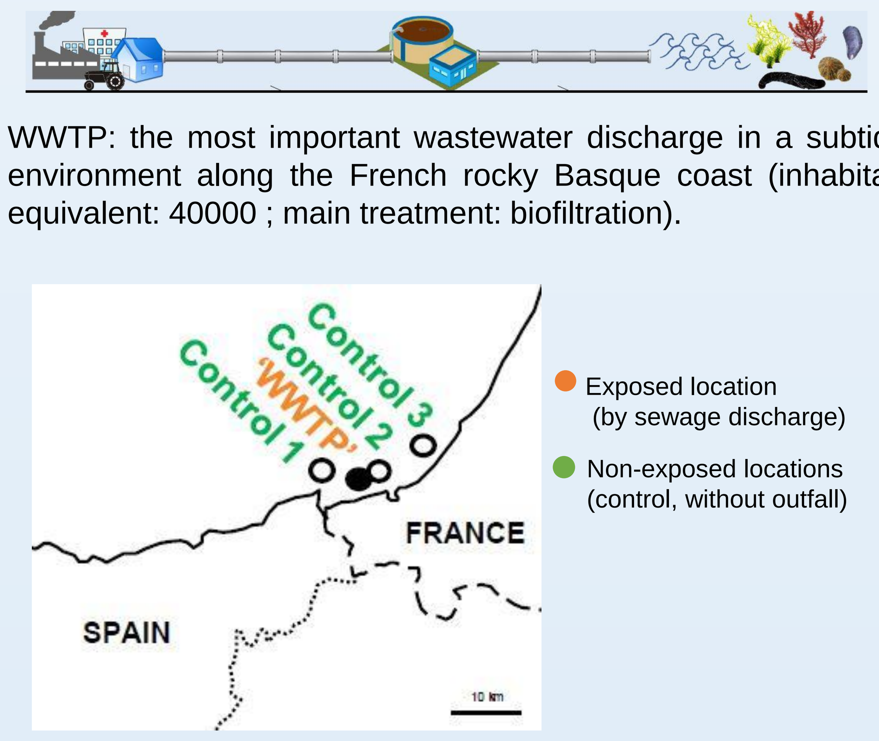

Fig.1: Study area - **1 exposed** and **3 control** locations along the **Basque coast** (France).

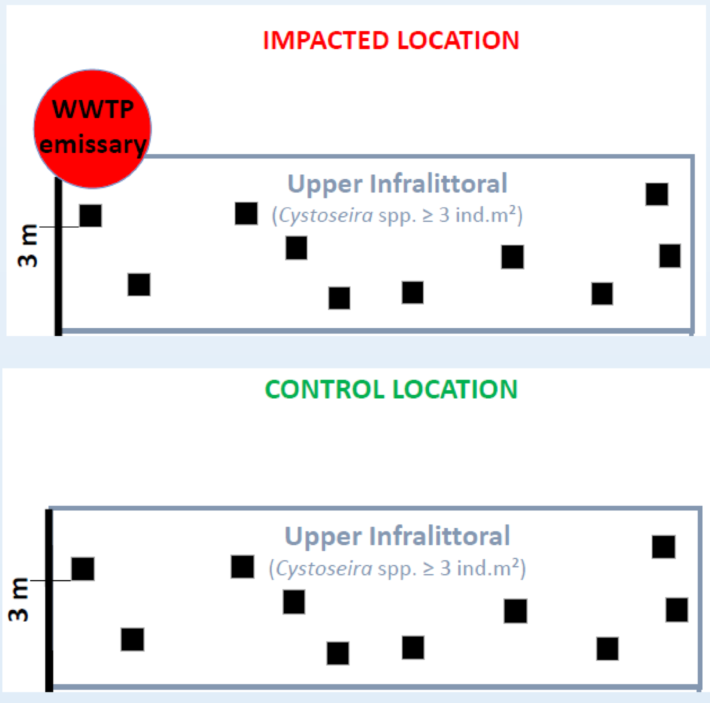

Fig.2: Control-Impact design in upper infralittoral zone for each location (impacted *vs* control), n=10 random quadrats.

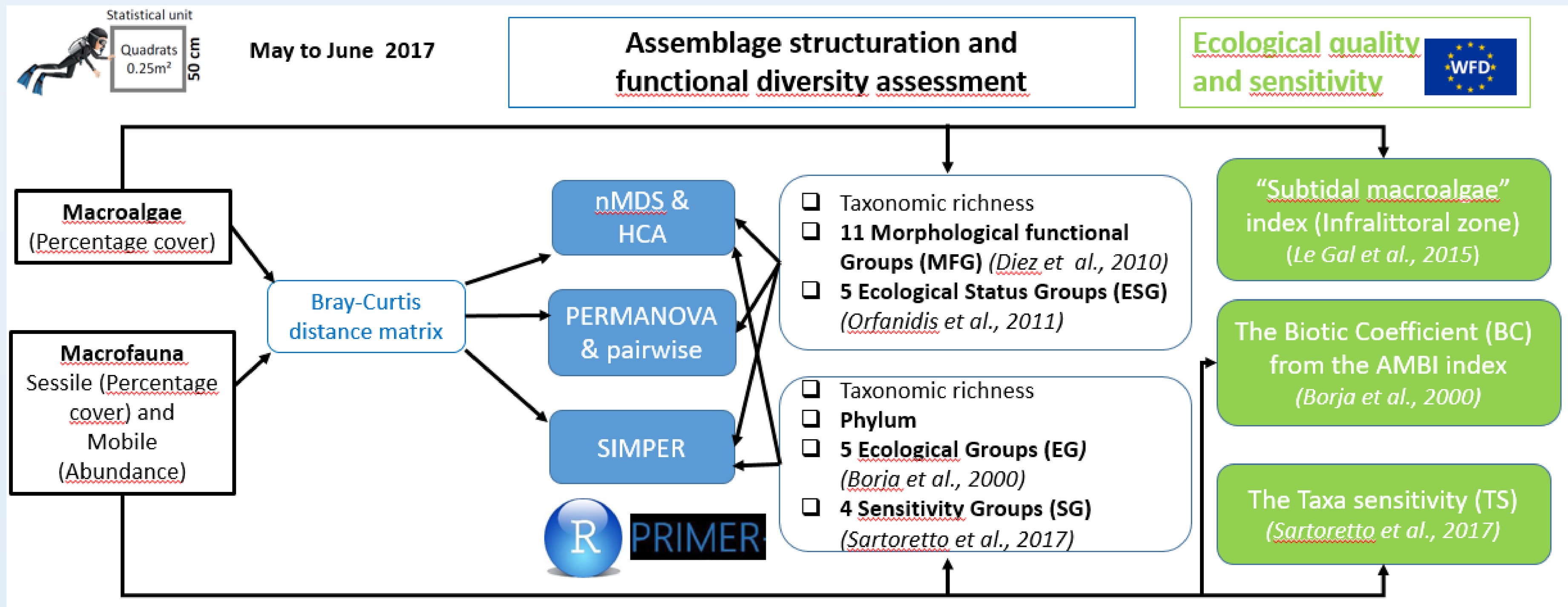

Fig.3: Methods (descriptors, metrics and statistical analyses).

RESULTS

Macroalgae

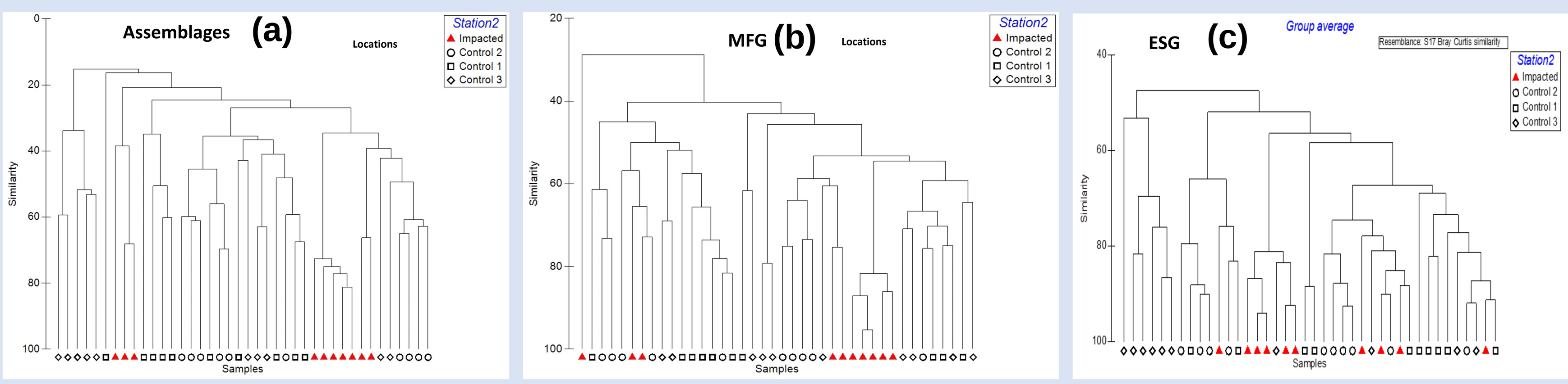

Fig.4: Non-metric multi-dimensional scaling plot (nMDS) computed on macroalgal assemblages (a), morpho-functional groups (MFG) (b) and ecological status groups (ESG) (c) at impacted and control locations in the upper infralittoral zone.

Assemblages (d) — IU_p vs. Controls

78.28%	av 'IU_p'	av 'Controls'	Ct (%)	Cum. Ct (%)	P-value	Significance
Gelidium corneum	47.30	8.70	20.84	20.84	0.001	***
Corallina spp.	19.40	7.13	8.36	29.20	0.027	*
Plocamium cartilagineum	12.70	3.80	5.13	34.33	0.003	**
Mesophyllum lichenoides	5.70	0.00	2.72	37.05	0.001	***
Nithophyllum punctatum	2.30	0.07	1.04	38.09	0.001	***

MFG (e) — IU_p vs. Controls

57.42%	av 'IU_p'	av 'Controls'	Ct (%)
Terete corticated	48.10	16.50	25.34
Foliose heavily corticated	8.90	3.40	6.53

ESG (f) — IU_p vs. Controls

47.04%	av 'IU_p'	av 'Controls'	Ct (%)
IIA	73.10	27.90	42.80

Tab.1: SIMPER analyses: contributors (Ct > 1%) to the dissimilarity between impacted and control locations computed on macroalgal assemblages (d), (MFG) (e) and ESG (f) in the upper infralittoral zone.

- 74 identified macroalgae (48 Rhodophyta, 19 Ochrophyta and 7 Chlorophyta).
- No significant difference between the potentially impacted location and controls for assemblages, MFG and ESG (PERMANOVA, p>0.05, Fig.4).
- *Gelidium corneum* more abundant in the impacted location (highest contribution to the dissimilarity (>20%). *Mesophyllum lichenoides* absent from the controls (Tab.1).
- Terete and foliose heavily corticated (MFG) and ESG IIA ("fleshy opportunistic") appeared significant contributors to the dissimilarity with higher abundances in the impacted location (Tab.1e,f).

Macrofauna

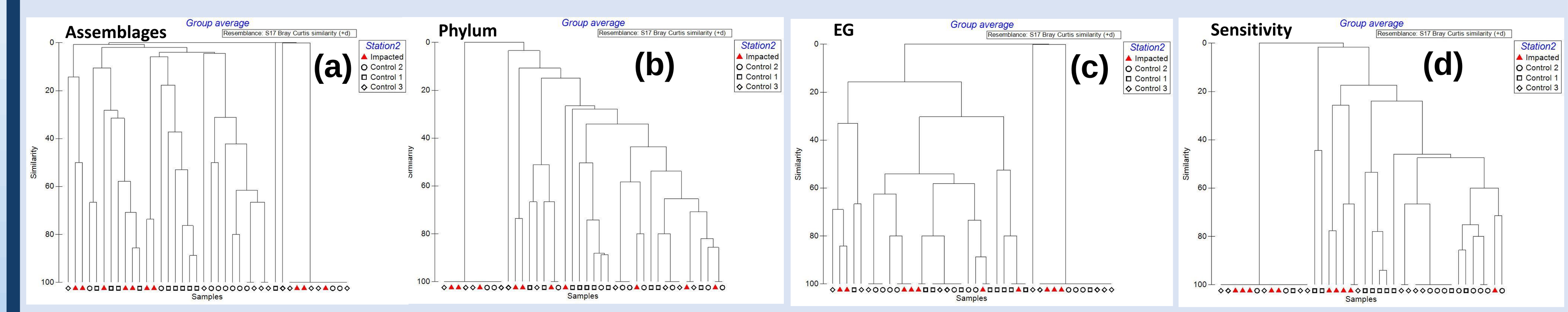

Fig.5: Non-metric multi-dimensional scaling plot (nMDS) computed on macrofaunal assemblages (a), phylum (b), Ecological Groups (EG) (c) and Sensitivity Groups (SG) (d)) at impacted and control locations in the upper infralittoral zone.

Assemblages (e) — IU_p vs. Controls

96.32%	av 'IU_p'	av 'Controls'	Ct (%)	Cum. Ct (%)	P-value	Significance
Botryllus schlosseri	2.43	0.00	18.79	18.79	0.023	*
Tritia reticulata	1.29	0.29	15.52	34.31	0.049	*
Actiniaria	0.29	0.00	5.88	69.25	0.004	**

Phylum (f) — IU_p vs. Controls

72.19%	av 'IU_p'	av 'Controls'	Ct (%)
Chordata	2.43	0.00	25.07

EG (g) — IU_p vs. Controls

61.31%	av 'IU_p'	av 'Controls'	Ct (%)
No significant contributor			

SG (h) — IU_p vs. Controls

79.34%	av 'IU_p'	av 'Controls'	Ct (%)
II	4.80	0.50	57.15

Tab.2: SIMPER analyses: contributors (Ct > 1%) to the dissimilarity between impacted and control locations computed on macrofaunal assemblages (e), phylum (f), Ecological Groups (g) and Sensitivity Groups (h)) in the upper infralittoral zone.

- 89 identified macrofauna.
- No significant difference for macrofaunal assemblages, phylum, ecological and sensitivity groups between impacted and control locations (PERMANOVA, p>0.05, Fig.5).
- *Botryllus schlosseri,Tritia reticulata* and order Actiniaria highlighted as significant contributors
- *B. schlosseri* and order Actiniaria absent from the controls (Tab.2e).
- Chordata (absent from the controls) and SG II (opportunistic taxa with higher abundances in the impacted location) significant contributors to the dissimilarity (Tab.2f,h).
- No significant contributor for EG (Tab.2g).

WFD	I	C1	C2	C3
	IU_p	$C1U_p$	$C2U_p$	$C3U_p$
Macroalgae				
Ecological Quality Ratio (EQR)	0.27	0.7	0.77	0.83
Ecological Quality Status class (EQS)	Poor	Good	Good	Good
Macrofauna				
Biotic coefficient (BC)	0.65	1.41	1	0.88
Pollution classification from BC	Unpolluted	Slightly polluted	Unpolluted	Unpolluted
Benthic community health from BC	Impoverished	Unbalanced	Impoverished	Impoverished
Taxa sensitivity (TS)	0.47	0.37	0.34	0.29

Fig.8: Ecological quality indices values calculated for both macroalgae and macrofauna per location (I: impacted ; C: controls ; Up: upper infralittoral zone).

Response of biological indices differed:

- Based on macroalgae: All controls were classed as "Good" and the impacted location as "Poor" (Fig. 8). Mainly due to: depth boundary of the algal belt (Metric 1), number of characteristic species (Metric 3a) and taxonomic richness (Metric 4). The density of structuring species (i.e. *Cystoseira* spp.) (Metric 2) also influenced this rating (Fig. 9).
- Based on macrofauna: By contrast, better scores were assigned to the impacted location: Acccording to the BC, the impacted location (lowest value) and controls were assigned to unpolluted location with impoverished community health excepted 'Control 1'(slightly polluted location with unbalanced community health). The higher TS value in the impacted location highlighted a greater sensitivity (Fig. 9).

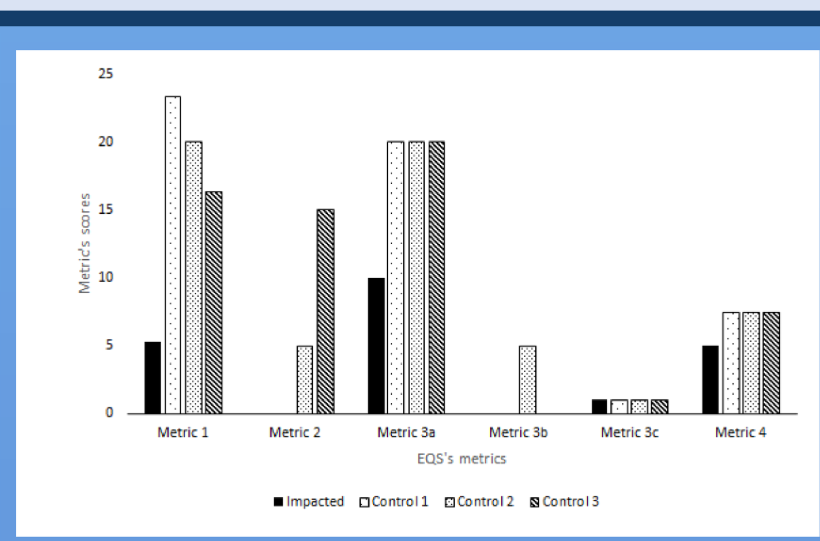

Fig.9: Scores of the metrics used to calculate the Quality Index (QI) and the Ecological Quality Status (EQS).

DISCUSSION AND CONCLUSION

- Both macroalgae and macrofauna were studied as required by European Directives to assess the response of biological indicators to various pressures. However, they showed different response to the WWTP disturbance.
- Macroalgae exhibit greater sensitivity than macrofauna, and multivariable techniques show greater precision in assessing the extent of the impact (moderate to slight) than the multimetric EQR approach (heavy). *Gelidium corneum*, a terete corticated Rhodophyta, was identified as a significant high contributor to the dissimilarity between the impacted location and the controls, with a higher abundance in the former. The fertilization of the water column coming from the outfall may explain the proliferation of *G. corneum* in the impacted location. Low inputs of nutrients (especially nitrogen) can promote the growth and greater photoprotection under strong irradiance and depletion of natural nutrients in the environment (Quintano *et al.*, 2017). This nutrient enrichment could be corroborate by the higher abundance of calcareous algae *Mesophyllum lichenoides* and *Corallina* spp around the outfall. The higher contribution in the upper infralittoral algal belt of opportunistic species (ESG IIA) at the impacted location also revealed a certain environmental stress.
- Descriptors and ecological indices based on macrofauna did not captured changes in structure between control and impacted locations. Consequently, the sampled macrofauna seem not to be a sensitive indicator to such disturbances in this type of habitat. A high dilution factor in the subtidal zone, a marked natural variability over the study area and a lack of knowledge of the sensitivity of many species could partially explain why no significant differences were detected between control and impacted locations. Moreover, new approaches have to be developed to integrate or evaluate more efficiently the response of macrofauna to such a pressure.

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