TEMPORAL TRENDS OF HEAVY METAL CONCENTRATIONS IN BROWN MACROALGAE FROM COASTAL ENVIRONMENTS

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INTRODUCTION

Metallic contamination is one of the most important drivers of global change in ecosystems worldwide. Especially since the industrial revolution, heavy metals and metalloids have been intensively discharged to the marine environment by human activities without adequate environmental control. Macroalgae are primary producers of great relevance for ecosystem structure and functioning in these environments, and play a key role in the trophic transfer of these contaminants across the food web. Brown macroalgae (Class Phaeophyceae) have been extensively used in multitude of research studies monitoring heavy metals worldwide because their ability to integrate high levels of contaminants from the environment. Only few literature sources have reported temporal trends in metal concentrations in brown macroalgae. Although restricted to short-term regionally circumscribed series, some of these studies (i.e. Viana et al., 2010; García-Seoane et al., 2021) have observed a decreasing in metal concentrations in macroalgae since the beginning of the XXI century in a small region of the North Atlantic Ocean coast.

OBJECTIVE

To determine whether these trends in the decrease of heavy metals in brown macroalgae are restricted to that small region during the past two decades or spread to other areas of the planet and previous times, while assessing the effectiveness of environmental policies implemented over time.

METHODOLOGY

The study compiles information (>3500 records, from 420 peer reviewed articles) of heavy metal concentrations in brown macroalgae sampled between 1933 and 2020 worldwide. Detailed multi-decadal time series of Cd, Co, Cr, Cu, Fe, Hg, Mn, Pb and Zn in different brown algae families are reported using generalized additive models (GAMs) runned in R statistical software.

References:

- Viana et al. (2010). Water Res. 44 (6), 1713-1724.
- García-Seoane et al. (2021). J. Haz. Mat. 412, 125268.

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PRELIMINARY RESULTS

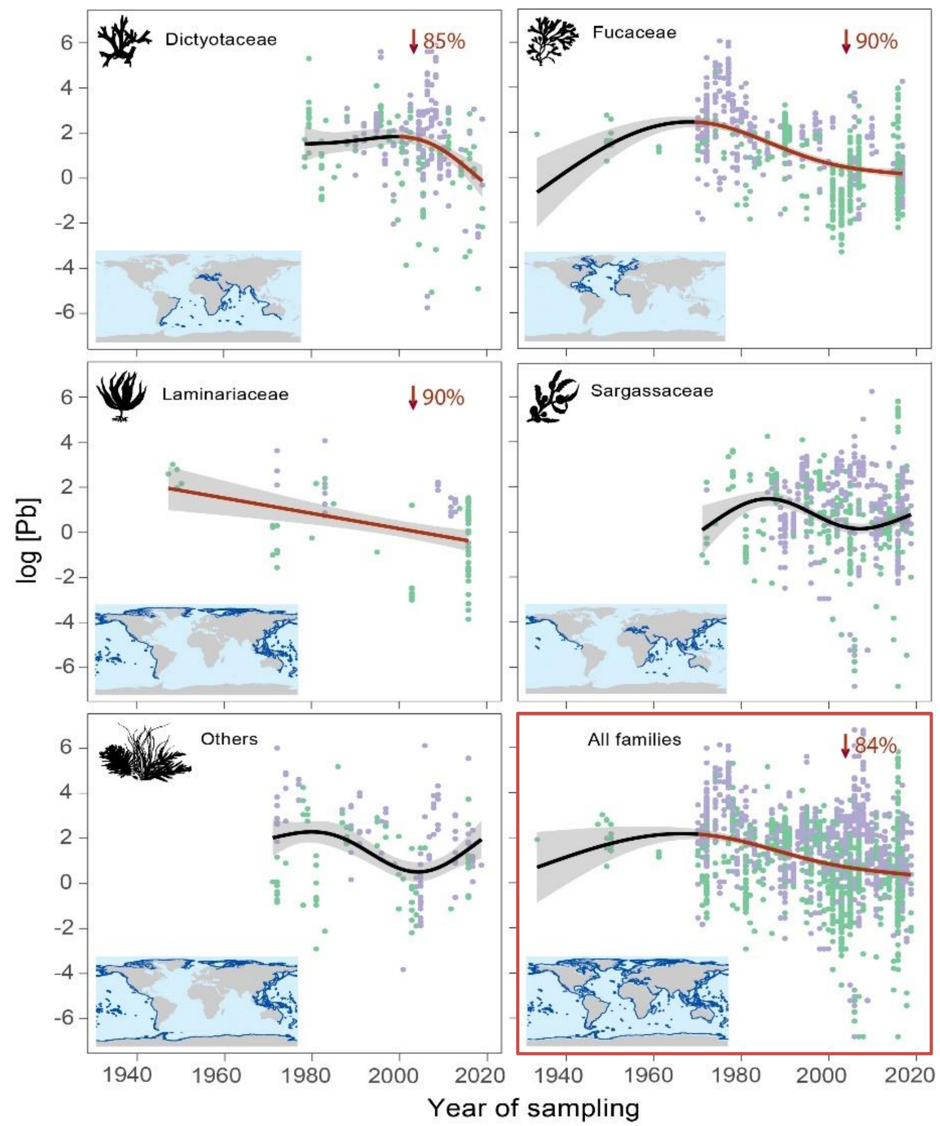

Fig. 1. Long-term temporal changes in Pb concentrations (log, µg g^{-1}) in different brown macroalgae families. Black solid line: GAM adjust. Grey area: 95% confidence interval in the GAM adjust. Dots: areas with (purple) and without (green) anthropogenic pressure. Maps correspond to the main area of distribution for each family in the compiled dataset.

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We observe a significant decrease in metal contamination in the world's coastal environments in the range of -44.9 to -95.9%, starting in the late 1960s and early 1970s for Cd, Cu, Pb and Zn, and late 1980s and early 1990s for Co, Cr, Fe, Hg and Mn, and continuing over the last 50 years. See Pb in **Fig. 1** as an example. Annual rates of decrease (ca. -2%), were fairly consistent across elements and families, although Dyctiotaceae reached the highest rates (from over -3 to -6%). See **Table 1** for more details.

Table 1. Variation in metal concentrations predicted by GAMs models. Significant decreases are shown in bold type.

Element	Family	Period	Initial concentration (µg g^{-1})	Final concentration (µg g^{-1})	Concentration variation (%)	Annual rate of decrease (%)
Cd	All	1970-2020	1.906	0.436	**-77.1**	1.6
	Fucaceae	1970-2017	2.991	0.456	**-84.7**	1.7
	Laminariaceae	2000-2020	2.239	0.220	**-90.2**	4.5
	Sargassaceae	1971-2020	0.901	0.577	-35.9	-
	Dyctiotaceae	2000-2020	1.131	0.147	**-87.0**	4.4
	Others	1971-2019	0.894	0.443	-50.5	-
Co	All	1990-2019	1.710	0.689	**-59.7**	2.1
	Fucaceae	1983-2017	4.660	0.426	**-90.9**	2.7
	Laminariaceae	1984-2016	0.494	0.043	**-91.4**	2.9
	Sargassaceae	1970-2019	1.076	1.635	52.0	-
	Dyctiotaceae	2004-2019	3.639	0.506	**-86.1**	5.7
	Others	1990-2019	1.710	0.539	-68.5	-
Cr	All	1993-2019	3.253	1.105	**-66.0**	2.5
	Fucaceae	1996-2017	4.390	1.037	**-76.4**	3.6
	Laminariaceae	1947-2014	1.411	2.305	63.4	-
	Sargassaceae	1973-2019	1.981	1.358	-31.5	-
	Dyctiotaceae	1978-2019	5.482	0.925	**-83.1**	2.0
	Others	1989-2019	7.927	1.983	-75.0	-
Cu	All	1968-2020	12.540	3.566	**-71.6**	1.4
	Fucaceae	1987-2017	19.783	6.186	**-68.7**	2.3
	Laminariaceae	1947-2016	36.434	1.497	**-95.9**	1.4
	Sargassaceae	1970-2019	9.034	4.475	-50.5	-
	Dyctiotaceae	1995-2020	7.381	1.846	**-75.0**	3.0
	Others	1970-2019	8.609	4.239	-50.8	-
Fe	All	1994-2019	413.805	149.427	**-63.9**	2.6
	Fucaceae	1995-2017	341.739	188.201	**-44.9**	2.0
	Laminariaceae	1947-2016	269.022	67.003	**-75.1**	1.1
	Sargassaceae	2002-2019	382.692	85.699	**-77.6**	4.6
	Dyctiotaceae	1998-2019	1223.729	149.219	**-87.8**	4.2
	Others	1970-2019	386.781	422.412	9.2	-
Hg	All	1983-2019	0.094	0.033	**-65.1**	1.8
	Fucaceae	1978-2017	0.133	0.019	**-85.7**	2.2
	Laminariaceae	-	-	-	-	-
	Sargassaceae	1985-2019	0.196	0.196	-0.1	-
	Dyctiotaceae	1980-2019	0.050	0.023	-53.2	-
	Others	1971-2016	0.197	0.051	-74.2	-
Mn	All	1985-2019	77.977	19.731	**-74.7**	2.2
	Fucaceae	1991-2016	126.869	79.377	-37.4	-
	Laminariaceae	1947-2016	17.712	5.863	-66.9	-
	Sargassaceae	1973-2019	66.277	14.062	**-78.8**	1.7
	Dyctiotaceae	1975-2019	112.409	13.019	**-88.4**	2.0
	Others	1970-2019	53.574	10.805	**-79.8**	1.6
Pb	All	1968-2019	8.544	1.369	**-84.0**	1.6
	Fucaceae	1970-2017	11.315	1.136	**-90.0**	1.9
	Laminariaceae	1947-2016	6.874	0.664	**-90.3**	1.3
	Sargassaceae	1987-2019	4.251	2.124	-50.0	-
	Dyctiotaceae	1999-2019	6.120	0.924	**-84.9**	4.2
	Others	1981-2019	9.209	6.647	-27.8	-
Zn	All	1968-2019	161.715	33.612	**-79.2**	1.6
	Fucaceae	1968-2017	301.969	115.885	**-61.6**	1.3
	Laminariaceae	1947-2016	116.001	34.933	**-69.9**	1.0
	Sargassaceae	1994-2019	22.914	12.377	**-46.0**	1.8
	Dyctiotaceae	1996-2019	40.833	7.349	**-82.0**	3.6
	Others	1970-2019	58.083	65.632	13.0	-

CONCLUSIONS

These results confirm a widespread change in the levels of metals affecting a substantial part of the coastal environments in the globe. It seems that some ecosystems are responding positively to the environmental policies implemented in recent decades against marine contamination. Important environmental consequences for the whole aquatic ecosystem, even for human health, may be expected from these changes.