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Use of Estuarine Water Quality Index (EWQI) as a tool to aid Oysters Aquaculture Production in Coastal Zone

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Introduction

Expansion of fish and oyster aquaculture in Sado estuary due to incentives (*e.g.* MAR2023)

Occurrence of other industrial activities and possible effluent discharges

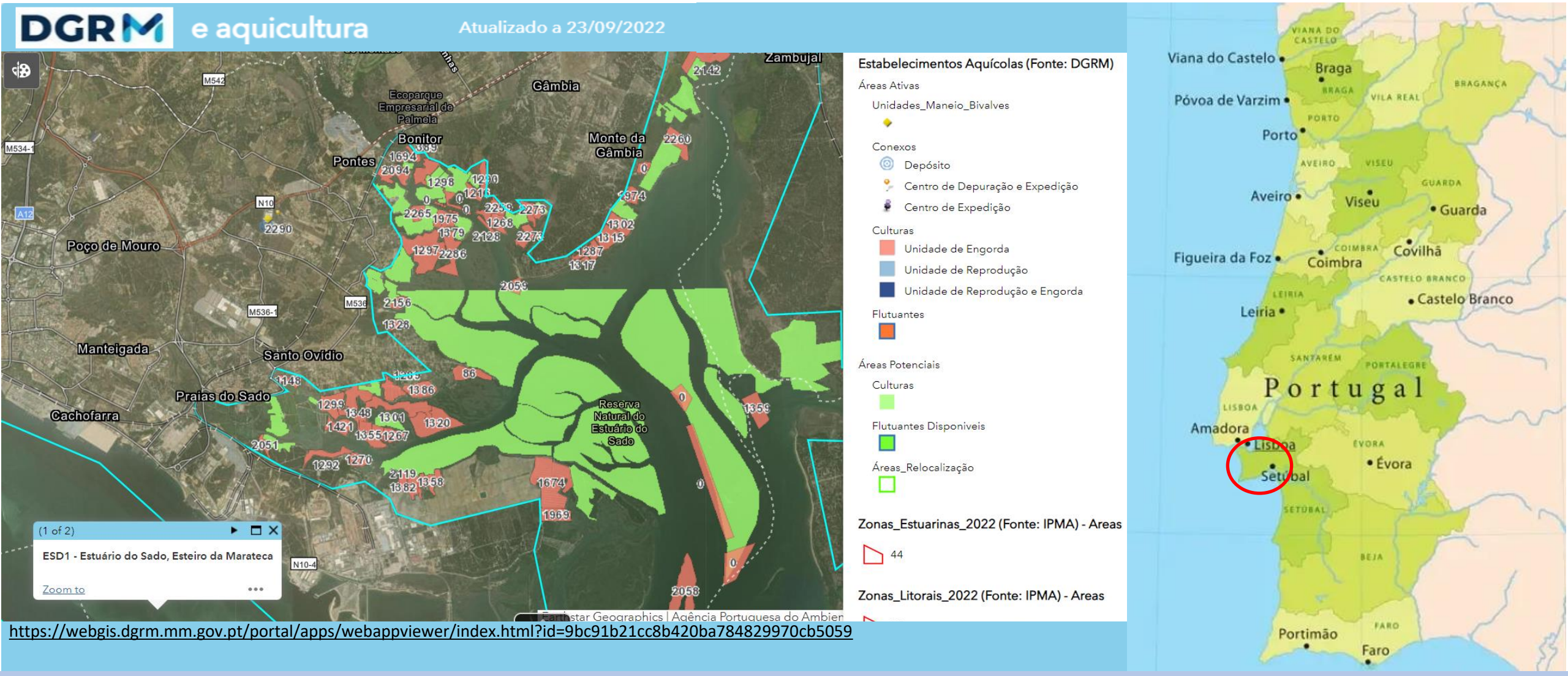
Importance of developing methodologies for monitoring water quality

Estuarine Water Quality Index (EWQI)

A tool to ensure better management of existing productions nearby (oysters and fish farms and industries)

Establish perimeters and define the best locations for the installation of new industries without harming the ecosystem and maintaining good water quality

Introduction



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Water Quality Index Development

Water Quality Index (WQI)

✓ WQIs simplify big amounts of data, filtering the most important to create an overall water quality image of the analyzed area:

Excellent | Good | Medium | Bad | Very bad

WQIs have been developed over several decades:

✓ 1965, Horton: 10 parameters

✓ 1970, Brown and panel of 142 water experts: variables, importance, rating curve -> NSF-WQI, 9 parameters

✓ 1978, Ott, solidify NSF-WQI

WQI for saline waters, *e.g.* estuarine waters

✓ Proposal for WQI are scarce

✓ Some parameters used on traditional WQI for fresh water make no sense (*e.g.*, total solids)

✓ New parameters are needed for a correct assessment of water quality (*e.g.,* chlorophyll)

Water Quality Index Development

16 parameters were measured

- ✓ *in-situ* parameters: pH, Temperature of water and air, Salinity, Conductivity, Dissolved Oxygen (DO), and Oxidation Reduction Potential (ORP).
- ✓ *ex-situ*, laboratory: Total Suspended Solids, Ammoniacal Nitrogen, Nitrites, Nitrate, Phosphate, Chlorophyll, Biological Oxygen Demand (BOD), Dissolved Organic Matter by Chemical Oxygen Demand (CODOH), and Particulate Organic Matter.
- ✓ 2 of the analytical methods used, COD and BOD have been previously **adapted** to saline waters.

Water Quality Index Development

Methodology for new EWQI development

- ✓ the individual importance and the intercorrelation of the 16 parameters were analyzed
- ✓ the most relevant parameters and their weight were selected, based on critical analysis of previous literature
- ✓ this new WQI is based on 7 parameters
- ✓ most sub-index calculation for each parameter were based on Ott equations

2 new sub-index equations were developed

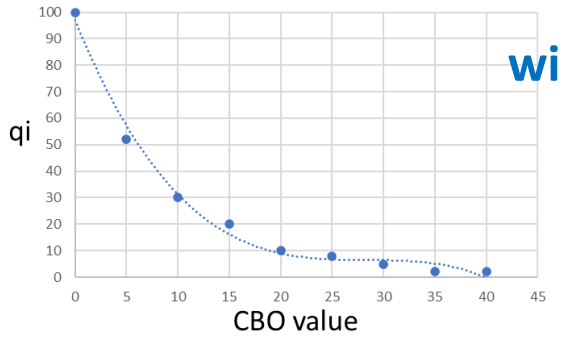
- ✓ chlorophyll, taking into account that nitrogen as the limiting nutrient, as is typical in Sado's estuary
- ✓ ammoniacal nitrogen, taking in account its higher fish toxicity at higher pH

EWQI (GI4SADO, 2022)			
PARAMETER		AUTHOR	WEIGHT (wi)
Dissolved Oxygen	(%)	Cooper et al., 1994	0.20
Biochemical Oxygen Demand	(mg/L O_2)	Johnston et al., 2019	0.15
Nitrate	(mg/L N-NO_3)	Johnston et al., 2019	0.15
Phosphate	(mg/L P-PO_4^{3-})	Cooper et al., 1994; Johnston et al., 2019	0.15
Total Suspended Solids	(mg/L)	Johnston et al., 2019	0.10
Chlorophyll	(µg/L)	Cooper et al., 1994	0.10
Ammoniacal Nitrogen	(mg/L N-NH_4+)	House, 1989 Cooper et al., 1994	0.15

Water Quality Index Development

Date	Hour	Nº Sample	Local	Latitude	Longitude	Temperature air (ºC)	Temperature water (ºC)	D.O. (mg/L)	D.O. (%)	pH	Salinity (g/kg)	Conductivity (mS/cm)
28/09/2021	16:30	56	**Praia**	38.417772ºN	8.714847ºW	24,90	24,81	6,15	72,8	7,90	36,4	54,9

28/	Total Suspended Solids (mg/L)	Chlorophyll (µg/L)	BOD (mg/L O2)	Ammoniacal Nitrogen (mg/L NH4)	Nitrites (mg/L NO2)	Nitrates (mg/L NO3)	Phosphate (mg/L N)	Dissolved Organic Matter (DOM: CQO-OH) (mg/L O2)	Particulated Organic Matter (POM) (mg/L)	ORP (mV)
	311	56,1	2,4	0,01	0,04	0,09	0	16,9	41,5	97,5
	207	13,4	1,8	0,23	1,87	0	0	3,9	19,5	78,5



wi = 0.15 **qi calculation**

81

EWQI = ∑ wi.qi

EWQI

WQI numerical range	Classification	Color
91-100	Excellent	Blue
71-90	Good	Green
51-70	Medium	Yellow
26-50	Bad	Orange
0-25	Very bad	Red

Source: Gandra, V., Salgado, R., Ribeiro, R.S. et al. Development of a water quality index as a management tool to Sado coastal estuarine areas. J Coast Conserv 27, 20 (2023).

Material and Methods

Legend

Inlet water from estuary

Outlet water from pond

- ✓ Sluices gates for management of water inlets and outlets directly dependent on the tide
- ✓ Water renewal by tide

- ✓ Pumping system for management of inlet and sluices gates for outlet water
- ✓ Aeration system in fishpond
- ✓ Retention/settling pond

Raw results

Data	Hora	Nº de amostra	Local	Observação	Temperatura ar (ºC)	Temperatura água (ºC)	Oxigénio dissolvido (mg/L)	pH	Salinidade (g/kg)	Condutividade (mS/cm)	Solidos Suspensos Totais (mg/L)	Clorofila (µg/L)	CBO (mg/L O2)	Amônia (mg/L NH4)	Nitritos (mg/L NO2)	Nitratos (mg/L NO3)	Azoto (mg/L N)	Dissolved Organic Matter (DOM: CQO-OH) (mg/L O2)	Particulated Organic Matter (POM) (mg/L)
22/09/2021	10h15	20 (entrada)	Boa água (entrada)			19,6	5,15	7,96	37,6	52,8	92,5	0	1,1	-	0	0,25	1,18	17,07	22
22/09/2021	10h00	21 (saída)	Boa água (saída)			19,8	4,31	8,03	37,6	51	141,5	20,03	2,3	-	0	0,2	1,29	16,60	24,5
22/09/2021	16h03	22 (entrada)	Boa água (entrada)			22,8	6,97	8,25	37,5	50,9	93,5	38,72	0,8	-	0	0,14	0,67	2,47	15
22/09/2021	16h13	23 (saída)	Boa água (Saída)			24,1	9,54	8,23	37,7	51,3	135,5	46,06	2,0	-	0	0,07	0,84	14,93	18,5
28/09/2021	9h30	24 (entrada)	Boa água (entrada)	Bomba ligada		21,2	6,22	8,07	38	55	171	49,4	6,0	-	0	0,06	0,45	17,73	31,5
28/09/2021	9h20	25 (saída)	Boa água (saída)			21,5	4,04	7,94	37,9	54,6	158	0	4,5	-	0	0,22	0,95	18,67	30
28/09/2021	16h00	26 (entrada)	Boa água (entrada)			23	6,92	7,84	37,7	54,5	115	0	4,2	-	0,04	0,15	1,35	14,13	31,5
28/09/2021	16h10	27 (saída)	Boa água (Saída)			23,2	7,36	7,99	38	49,8	168	37,38	5,0	-	0	0,14	0,51	18,27	38,5
07/10/2021	9h30	28 (entrada)	Boa água (entrada)			20	3,1	7,91	36,7	45,5	83,5	17,36	10,3	0,003	0	0	1,57	20,00	17
07/10/2021	9h40	29 (saída)	Boa água (saída)			19,9	4,06	7,98	37	45,7	123	17,36	6,3	0	0	0,19	0,9	19,53	17,5
07/10/2021	16h00	30 (entrada)	Boa água (entrada)	Bomba ligada		22,7	6,37	8,3	36,8	44,1	77	30,71	7,3	0	0,01	0,34	0,67	19,20	11
07/10/2021	16h10	31 (saída)	Boa água (Saída)			24,6	5,48	8,16	36,8	43,5	113,5	34,71	4,6	0	0,2	0	0,28	21,60	18
14/10/2021	9h30	32 (entrada)	Boa água (entrada)	Bomba ligada		20,6	6,57	8,91	36,7	45,5	194	14,69	4,4	-	0,15	0,03	0,22	5,07	11,5
14/10/2021	9h40	33 (saída)	Boa água (saída)			20,7	2,68	7,83	37	45,7	73	12,02	4,4	0	1,14	0,36	0,11	5,20	25
14/10/2021	16h00	34 (entrada)	Boa água (entrada)			22,7	3,97	7,91	36,8	44,1	88	0	3,1	0	1,31	0	0,62	1,73	22,5
14/10/2021	16h10	35 (saída)	Boa água (Saída)			23,1	4,45	7,95	36,8	43,5	163	10,68	4,2	0,038	0	0,05	0	7,60	30
09/11/2021	10h08	36 (entrada)	Boa água (entrada)		14,67	14	6,1	7,88	34,7	53,2	85	6,68	5,0	0	0,35	0	0	0,80	14
09/11/2021	9h58	37 (saída)	Boa água (Saída)		14,67	13,9	6,19	7,76	34,6	53,1	87	20,03	6,6	0	0,51	0	0	7,53	14
09/11/2021	16h03	38 (entrada)	Boa água (entrada)		19,1	15,9	3,37	7,66	34,7	53,2	131	10,68	7,1	0	0,35	0	0	19,60	17,5
09/11/2021	16h12	39 (saída)	Boa água (Saída)		19,1	16,9	6,88	7,79	34,8	53,2	197,5	0	6,4	0	0,46	0	0	8,40	30
17/11/2021	15h47	40 (entrada)	Boa água (entrada)	Bomba ligada	22,3	14,8	8,3	8,45	34,3	52,9	82,5	0	1,4	0,018	0,32	0	0	4,13	15,5
17/11/2021	15h43	41 (saída)	Boa água (Saída)		22,3	17,1	8,41	8,25	34,6	53,5	92,5	8,01	1,9	0,138	1,31	0	0,06	5,47	15
24/11/2021	16h24	42 (entrada)	Boa água (entrada)	Bomba ligada	12,5	13,3	8,47	8,07	34,6	54,1	122,5	5,34	1,6	0,016	0,35	0,18	0	7,00	30
24/11/2021	16h29	43 (saída)	Boa água (Saída)		12,5	13,5	7,46	7,9	34,6	54,3	181	17,36	2,5	0,04	0,51	0,1	0,34	8,80	34

EWQI determination

					Weight proposed for EWQI (Wi):			0,2		0,1		0,1		0,15		0,15		0,15	
Data	**Hora**	**Nº de amostra**	**Obs**	**Temperatura água (ºC)**	**Oxigénio dissolvido (mg/L)**	**O2 de sat. (100%)**	**D.O. (% sat.)**	***sub-index OD***	**Solidos Suspensos Totais (mg/L)**	***sub-Index SST***	**Clorofila (µg/L)**	***sub-Index Clorofila***	**CBO (mg/L O2)**	***sub-Index CBO***	**Amônia (mg/L NH4)**	***sub-Index Amonia***	**Nitratos (mg/L NO3)**	***sub-Index Nitratos***	**WQI_IPS et al 2022**
22/09/2021	10h15	20 (entrada)		19,6	5,15	9,17	56,17	52,8	92,5	34,8	0	98,1	1,1	87,9	-	10,0	0,25	98,5	53
22/09/2021	16h03	22 (entrada)		22,8	6,97	8,61	80,93	81,3	93,5	34,2	38,72	10,0	0,8	90,9	-	10,0	0,14	99,2	51
28/09/2021	9h30	24 (entrada)	Bomba ligada	21,2	6,22	8,88	70,04	68,7	171	10,0	49,4	10,0	6,0	10,0	-	10,0	0,06	99,6	34
28/09/2021	16h00	26 (entrada)		23	6,92	8,58	80,65	80,9	115	24,0	0	98,1	4,2	58,3	-	10,0	0,15	99,1	54
07/10/2021	9h30	28 (entrada)		20	3,1	9,10	34,08	27,4	83,5	40,3	17,36	34,6	10,3	10,0	0,003	99,0	0	100,0	44
07/10/2021	16h00	30 (entrada)	Bomba ligada	22,7	6,37	8,63	73,82	73,1	77	44,8	30,71	23,7	7,3	10,0	0	99,0	0,34	98,0	53
14/10/2021	9h30	32 (entrada)	Bomba ligada	20,6	6,57	8,99	73,11	72,3	194	10,0	14,69	40,7	4,4	56,4	-	10,0	0,03	99,8	44
14/10/2021	16h00	34 (entrada)		22,7	3,97	8,63	46,01	41,1	88	37,4	0	98,1	3,1	68,5	0	99,0	0	100,0	62
09/11/2021	10h08	36 (entrada)		14	6,1	10,33	59,03	56,1	85	39,3	6,68	67,0	5,0	10,0	0	99,0	0	100,0	53
09/11/2021	16h03	38 (entrada)		15,9	3,37	9,91	34,00	27,3	131	18,5	10,68	52,4	7,1	10,0	0	99,0	0	100,0	44
17/11/2021	15h47	40 (entrada)	Bomba ligada	14,8	8,3	10,15	81,75	82,2	82,5	41,0	0	98,1	1,4	84,6	0,018	99,1	0	100,0	73
24/11/2021	16h24	42 (entrada)	Bomba ligada	13,3	8,47	10,50	80,69	81,0	122,5	21,3	5,34	72,6	1,6	83,2	0,016	99,1	0,18	98,9	68

EWQI

91-100	Excellent
71-90	Good
51-70	Medium
26-50	Bad
0-25	Very bad

Results – Fish Farm

Fish farm		
Date	**WQI in**	**WQI out**
22/09/2021	53	41
28/09/2021	54	37
14/10/2021	62	54
09/11/2021	53	50
17/11/2021	73	69
24/11/2021	68	59

EWQI

91-100	Excellent
71-90	Good
51-70	Medium
26-50	Bad
0-25	Very bad

The outlet water from fish farms tends to have a slightly lower quality than the inlet water

This was expected due to fish excretion and to the food supply not consumed

OUT water quality does not get worst since it is none intensive fish farm and tanks are aerated promoting some water depuration

Results – Oyster Farm

Months	Oyster Farms	
	WQI in	WQI out
June	55	72
July	69	74
September	54	56
October	50	49
November	64	64

EWQI

91-100	Excellent
71-90	Good
51-70	Medium
26-50	Bad
0-25	Very bad

The outlet water from Oyster farms tends to have a better quality than the inlet water

↓

Generally, the water quality improves as expected, since oysters are filter-feeding organisms

↓

Oyster aquaculture can contribute to water depuration

Conclusion

- ✓ The application of EWQI on fish and oyster farms water (IN and OUT) was successful and differences were found as expected: the OUT water from fish farms tends for a slightly lower quality, and for the opposite, the OUT water from oyster farms, tends to have a better quality
- ✓ These results are important and interesting, showing that the Sado estuary could benefit from combined and integrated farm systems such as sequential: fish farming **->** microalgae -> oyster aquaculture, combined in a multitrophic system
- ✓ The EWQI has proven to be an easy-to-use tool and will be further developed to integrate the CoastNet platform (Portuguese Coastal Monitoring Network), where data is online with free access
- ✓ This tool can also allow producers to access essential information for aquaculture planning and management.

Acknowledgment

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GI4SADO link:
https://romeuribeiro1998.wixsite.com/gi4sado

Enhancing and promoting the oyster aquaculture quality in Sado and Mira region, funding by FCT

OSTRAQUAL link:
https://ricardosalgado00.wixsite.com/ostraqual

Thank you for your attention!

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