ATLAS OF ENVIRONMENTAL RISK OF WATER QUALITY FOR PORTUGUESE MARINAS

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Abstract
This study applies the Pressure-State-Response (PSR) model to assess the environmental risk of marinas along the coast of mainland Portugal. The goal is to provide decision-makers, such as government agencies and harbour managers, with scientifically-based information that helps to manage marinas and neighbouring waterfronts. The classification and hierarquization of the risk is applied to 27 marinas along the west and south Portuguese coast. The environmental risk shows an assymetrical distribution with marinas having low risk in the west Atlantic coast and high to very high risk in the Algarve.The resulting maps can help establish priorities for intervention plans aimed at enhancing water quality.

Keywords: Pollution, Mapping, Coastal management, North Atlantic

Marinas play a key role in supporting recreational sailing activities and are integral infrastructures within coastal and maritime tourist sectors. They often encompass a wide variety of ecosystems that are under intense environmental change due to pollution, eutrophication and urbanization, among other pressures. Despite their significance, marinas in many parts of the world, including Portugal, lack the application of simple methodologies designed to provide a quick and cost-effective assessment of environmental risk based in existing data, that can be applicable uniformly to a large number of marinas. Here we follow the methodology proposed by Gómez et al. (2019) to map the spatial variability of risk factors for water quality in the principal marinas along the coast of mainland Portugal. The first step of the method consists of estimating the environmental pressures (Pri) related to the human activities with negative impacts in water quality at each marina. The indicators for pressures include the density of boats (berth/m^2), the presence of gas stations and dry docks, the frequency of dredging operations and the types of land use developed in a 1 km buffer surrounding the marina. The second step includes the assessment of environmental conditions at each marina described by a functional relationship between the environment's susceptibility to disturbance, the ecological value, and the naturalness of the environment. The indicators for the environmental state (Sti) are a combination of the flushing capacity of the water volume where port activity takes place, the number of ecological singular elements such as the protected areas in the marina's vicinity and a parameter for the marina's typology (anchorage or harbour) used as a proxy for naturalness. The third step considers the management actions, or responses (Rpi), applied at the marina level to mitigate and prevent the effects of human pressures. The indicators for responses are the number of adopted measures and instruments to reduce the pressures and improve the environmental performance, such as for example waste management practices and Blue Flag instruments.

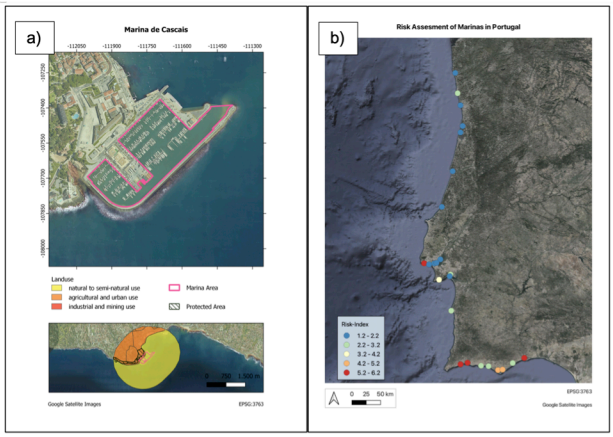

Fig. 1. a) Example of delimitation of areas and land use classification for the computation of the pressures and state indicators. b) Atlas of environmental risk of water quality for Portuguese marinas. Risk is classified into five classes: very Low, Low, Moderate, High, and very High.

The risk-index on water quality is the multi-parametric index defined for each marina as Ri = Pri x Sti + Rpi (Gómez et al., 2019). A database with the characteristics of each marina was compiled based on information from Marinas de Portugal. For all marinas the digitalization needed to compute the indicators, parameters and metrics was performed using GIS, Google Earth Satellite Images and CORINE Land Cover Data. Figure 1a shows an example of the data classification and buffers considered to estimate the indicators and metrics of environmental risk. All the indicators are normalized by the maximum value obtained. The thresholds for defining classes for Pressures, States and Responses have been defined specifically for Portugal (Table 1).

Tab. 1. Criteria to evaluate Pressures, State and Response categories for the Portuguese marinas.

Factor	Category	Criteria	Portuguese thresholds
Pressures (Pr)	VL (2/16)	Pri ≤ P25	Pri < 2
	L (14)	P25 < Pri ≤ P50	Pri = 2
	M (9)	P50 < Pri ≤ P75	2 < Pri ≤ 3
	H (1)	Pri > P75	Pri > 3
State (St)	VL (7)	Sti ≤ P25	Sti ≤ 0,6
	L (6)	P25 < Sti ≤ P50	0,6 < Sti ≤ 0,73
	M (7)	P50 < Sti ≤ P75	0,73 < Sti ≤ 1,5
	H (6)	Sti > P75	Sti > 1,5
Response (Rs)	Optimal (13)	Rsi ≥ P50	Rsi ≥ 0
	Insufficient (13)	Rsi < P50	Rsi < 0

VL: Very low; L: low; M: moderate; H: high; P25: 25th Percentile; P50: 50th

The multi-parametric index of the environmental risk for water quality was computed for the main 27 marinas along the Portuguese coast (Figure 1b). The distribution of the risk is not homogeneous with most marinas in the north displaying very low risk. The marinas with high and very high risk are mostly concentrated in South Portugal. The ones with the highest risk are Lagos and Portimão in the western sector of the Algarve. The factors that most contribute to the risk in Portimão are the pressures, namely the dredging and navigation activity. In Lagos, the factor that dominates the risk is the susceptibility which is related to the flushing capacity of the water volume combining hydrodynamic and morphological characteristics of the Marina through the Complexity Tidal Range Index. These marinas have implemented effective measures and instruments, as they demonstrate the highest levels of response through their current practices. Nevertheless, they should maintain their focus on environmental planning actions to further mitigate the environmental risk.

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