Collaboration for Environmental Evidence

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Systematic Map Protocol

Title
What evidence exists on the effectiveness of algae as biomonitors of pollution on estuaries?

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aquatic toxicology, algae, water pollution, nature based solutions, phycology

Background
Estuarine coastal regions play a critical role in global aquatic ecosystems, providing essential benefits such as diverse marine habitats, support for local economies through fisheries and tourism, and serving as important carbon stocks (Weatherdon et al., 2016; Martin et al., 2016). Nonetheless, these invaluable, dynamic and complex habitats are under increasing threat from human-induced pressures, including pollution from agricultural runoff to sewage discharge, emphasizing the urgent need for innovative monitoring and mitigation strategies. Traditional biomonitoring methods involve the use of indicator species such as fish and benthic macroinvertebrates; however, these can be limited in their ability to detect pollution at an early stage. As a result, alternative monitoring strategies such as the use of algae have become increasingly popular due to their abundance, sensitivity to changes in water quality (Torres et al., 2008; Stevenson, 2014). Previous research recognizes the capacity of various algae species to accumulate pollutants, thereby serving as reliable indicators of ecological stress and water contamination (Omar, 2010; Gherib et al., 2018). Despite the growing acknowledgment of their potential, a comprehensive evaluation of the effectiveness of algae as biomonitors in estuaries remains without a systematic review. This map, therefore, seeks to synthesize existing knowledge on the applicability and reliability of algae for coastal environmental monitoring, aiming to highlight existing knowledge gaps for a future systematic review. By focusing on the utility of algae in estuarine contexts, this study aspires to provide a comprehensive overview of current practices, and propose recommendations. Such an endeavor is crucial for directing future research, informing stakeholders, and guiding policy formulation towards more sustainable and effective environmental management of estuaries. This map aims to be a valuable resource for those involved in the management and preservation of estuarine environments, contributing to discussions on sustainable water management and ecological conservation.

Theory of change or causal model
Algae utilizes nutrients from the polluted environment to grow, as well as it can bioaccumulate and biodegrade chemicals on water. Due to their ability to bioaccumulate, algae could be a more useful indicator for detecting pollution at an early stage.

Stakeholder engagement
Embedded within the "RadiCAl - Radiocarbono e Algas" PhD research project at Fluminense Federal

University, in partnership with Infinito Mare and supported by CNPq, this protocol advances a systematic examination of chemical pollutants' impacts on coastal and estuarine algae. This research is a direct response to the urgent need for sustainable coastal management solutions, aligning closely with the United Nations Sustainable Development Goals (SDGs), particularly Goal 14, which calls for the conservation and sustainable use of the oceans, seas, and marine resources. By meticulously investigating the complex dynamics between algae and chemical contaminants, the study aims to uncover critical insights for closing existing knowledge gaps. These findings will empower policymakers with science-based tools and strategies, fostering sustainable policies that protect and enhance marine biodiversity. This initiative champions an integrative approach to environmental stewardship, demonstrating a proactive commitment to global sustainability objectives and ensuring healthier marine ecosystems for future generations.

Objectives and review question

The primary question of this review is: What evidence exists on the effectiveness of algae as biomonitors of pollution in estuaries?

Definitions of the question components

Components of the primary question Population: algal species on estuaries Exposure: types and concentration of natural and human-produced chemical substances Comparator: population not exposed to pollution; population prior to pollution exposure/ population exposed to different concentrations of pollution Outcome: All outcomes related to estuarine algae being used as biomonitors of pollution, from molecular to community levels. The outcomes related to algae as biomonitors of pollutants in estuaries will be considered including but not restricted to those presented in Figure 1.

Search strategy

The systematic map will follow the Collaboration for Environmental Evidence Guidelines and Standards for Evidence Synthesis in Environmental Management (CEE) and it conforms to ROSES reporting standards (Haddaway et al., 2018) (see Additional file 1). Searches will be performed using search terms exclusively in English language. This search however retrieved articles written in languages other than English and will not be included (see section “Eligibility criteria”). The list of search terms is presented in the next section (see section “Search string”). Search string A combination of search terms was obtained based on Ouédraogo et al., 2020 that performed a similar approach for coral reefs after a scoping exercise using ‘litsearchR’ package as Web Of Science format: TS = ((alga* OR seaweed OR macroalga* OR microalga* OR phytoplankton) AND (estuary OR estuaries OR estuarine) AND (contamin* OR toxicant$ OR pollut* OR "industrial discharge$" OR "sewage effluent$" OR "terrestrial runoff$" OR "agricultural runoff$" OR sewage OR eutrophication OR wastewater OR sedimentation OR nutrient$ OR pesticide$ OR herbicide$ OR insecticide$ OR fungicide$ OR "antifouling agent$" OR "non-agricultural biocide$" OR metal$ OR heavy metal OR organochlorine$ OR petrochemical$ OR solvent$ OR hormone$ OR “transformation product$" OR “degradation product$" OR byproduct$ OR "flame retardant$" OR detergent$ OR antibiotic$ OR "oil product$" OR dispersant$ OR "organic compound$" OR PCB$ OR PAH$ OR pharmaceutical$ OR "personal care product$" OR "UV filter$" OR microplastic$ OR nanoparticle$ OR "endocrine disrupting compound$" OR "perfluorinated compound$" OR hydrocarbon$ OR "oil spill$" OR phthalate$ OR biocide$) AND (biomonitor* OR detection OR monitor*)).

Bibliographic databases

The Federal Fluminense University institutional subscription will be used to search two bibliographic databases: Web of Science Core Collection and Scopus. The searches will include 'Topic' (i.e., title, abstract, author keywords) for WoSCC and 'Title, Abstract, Keyword' for Scopus.

Web-based search engines
The search string developed during the scoping exercise on WoSCC database will be adapted to fit the search facilities of these search engines (Additional file 4). Searches will be performed on titles, then the results will be sorted by relevance and the first 400 hits will be extracted. Results from Google Scholar will be extracted using the software Publish or Perish version 8.12.4612 (12 March 2024 (https://harzing.com/resources/publish-or-perish, accessed 30 March 2024).

Organisational websites
N/A

Comprehensiveness of the search
To assess the comprehensiveness of the search string, we used a test list of 15 articles considered by the review team as relevant to answer our question and spanning a wide range of chemicals (Additional file 3).

Search update
If more than two years have passed between the search and submission for publication, an update on search terms will be conducted.

Screening strategy
Articles will be screened for eligibility in two successive stages: first on titles and abstracts, and second on full-texts. Titles and abstracts will be imported to CADIMA (https://www.cadima.info/index.php), which is an online evidence synthesis tool. Duplicates are removed and publications evaluated. Articles with unclear eligibility status during title/abstract screening will be included for full text screening. The list of articles with unclear eligibility status after completion of full-text screening will be provided with explanation of why they could not be classified. Articles without an abstract and retained based on title screening will directly be screened on their full-text. Screening will be performed by at least two reviewers. One reviewer will evaluate articles based on their titles and abstracts first, and a subset of 5% of the publications will be reviewed by a second reviewer to review for consistency. A statistic coefficient Cohen's kappa will be calculated to evaluate the level of agreement between reviewers. If the kappa index suggests inconsistency ($k < 0.5$), the discrepancies will be discussed and resolved through changing inclusion/exclusion criteria if necessary. The publications will then be evaluated based on their full text by the same single reviewer. A subset of 10% of the publications will be assessed by a second reviewer. Again, after kappa index evaluation, any discrepancies will be discussed and resolved. Articles excluded at the second stage will be provided in an appendix at full text, with the reasons for exclusion.

Eligibility criteria
The publications must fulfill the following criteria to be included: Relevant subjects: brackish or estuarine coastal regions. Marine, or freshwater lakes or rivers will not be considered in this review. Relevant types of exposure: algal presence and characteristics. This includes any estuarine algal species (e.g., red, green or brown genera) exposed to all natural and synthetic chemicals coming from human activities. Relevant types of comparator: comparing community through a period of exposure to contaminants, comparing algal tissue exposed to chemicals and population prior to exposure, comparing algae exposed to a range of concentrations/levels of chemicals. Relevant types of outcome: All outcomes related to algae, from molecular level (e.g. gene expression, enzyme activities) to community level (e.g. symbiotic relations, species richness). Also, any measures of concentration, accumulation/uptake of chemicals in the studied population. Different impacts on algal community, algal growth rate, or abundance will also be considered. Relevant types of study: All primary field (in-situ) studies – not reviews, modeling, laboratory-based studies since these do not

answer the question. The studies may be from any year (no cut-off point) until the present (2024). Language: full texts written in English, only. The list of articles rejected at full-text screening will be provided with their reasons for exclusion. Reviews and meta-analyses will be excluded but those eligible according to the Population-Exposure-Comparator-Outcome criteria will be listed in a separate file to make them easily accessible for possible further use.

Consistency checking
Detailed in the 'Screening strategy' section.

Reporting screening outcomes
A flow diagram following the ROSES framework will be created to document the screening results. Articles that were excluded based on title and abstract will be listed in one file, while a separate file will document articles excluded at full text along with explanations for their exclusion. Any departures from this procedure will be disclosed and described.

Study validity assessment
No critical appraisal of studies will be performed. However, studies will be classified according to whether the paper's researchers have any involvement with the authors or not.

Consistency checking
N/A

Data coding strategy
For all studies included in the map, a detailed CodeBook of variables will be available using a Microsoft Excel sheet, with exhaustive information made available (Additional file 5).

Meta-data to be coded
This documentation will encompass bibliographic details such as unique identifier, source, title, authors, journal, year, DOI, language, and publication type. It will also include a general description of the study detailing publication content, the country of origin, and location by latitude and longitude. The dataset will describe the study population in terms of taxon and taxon level, the nature of exposure as mentioned by the original authors and as categorized by the review team, and the types of outcomes.

Consistency checking
The data coding process will be informed by an a priori specified CodeBook (refer to Additional file 5) and will be conducted by at least two independent reviewers. The codebook used for assessing evidence of chemical impacts on coral reefs by Ouédraogo et al. 2020 will be a reference for this process.

Type of mapping
We will produce a database (Microsoft Excel sheet) of all included studies and their coded data.

Narrative synthesis methods
This database will be open access and available as an appendix to the systematic map publication. In the map report, a narrative synthesis approach with descriptive statistics, tables and figures will be used to represent the geographical distribution of the included studies as well as their frequencies in the categories specified in the CodeBook. A matrix showing the distribution and frequency of included study into types of exposure and types of outcomes will be computed. The types of exposure and outcomes a priori defined in the CodeBook will be used, but new types may emerge during the meta-coding process.

Knowledge gap identification strategy
The matrix will be plotted as a heat map to visually identify potential knowledge gaps and knowledge clusters. We will thus identify the clusters(s) for which a full synthesis of evidence (systematic review) should be possible.

Demonstrating procedural independence
All data generated or analyzed during this study are included in this published article and its supplementary information files. In the case that self-citation is identified during the review process, any team member responsible for the cited work will abstain from the inclusion and critical appraisal of those specific articles. An independent and impartial reviewer will be designated to assess these articles to ensure an unbiased review process and to avoid any influence of self-citation on the work's outcome.

Competing interests
DT, JF, and BG are founders of the private company "Infinito Mare" that created the Caravela, a nature-based solution that uses algae to monitor and mitigate water pollution.

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Author's contributions
The first scoping exercise to build the search string was performed by DT. Then CC and BG refined it and all authors discussed and approved the final search string. DT produced a first draft of the manuscript that was revised by all the authors. All authors read and approved the final manuscript.

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