

The paper by Kotta et al. 2024 (<https://doi.org/10.1007/s10750-024-05619-x>) presents a framework designed to assess the environmental impact of marine non-indigenous species (NIS) across varying levels of data availability. This universal framework is adaptable to different ecological and data contexts, enabling a more consistent and accurate evaluation of the effects these species have on marine ecosystems. The framework is intended to support decision-making processes in marine management and conservation by providing a standardized approach to assess and compare the impacts of NIS, even in situations where data is limited or incomplete.

Background: Current methods for assessing the environmental impacts of NIS are hindered by insufficient data, excessive reliance on expert judgment, and overly coarse spatial resolution, all of which impede precise local management. We are in an era of rapidly expanding data on the environmental impacts of NIS, overwhelming experts' ability to access and objectively assess this information. To improve management decisions, there must be a shift from reliance on expert judgment to data-driven analysis and modeling.

Framework: This study addresses a critical gap in NIS management by introducing a comprehensive and practical framework that integrates systematic reviews, meta-analyses, species distribution modeling, and expert judgment to assess the impacts of NIS across different levels of information availability. The framework also suggests complementary, under-utilized data sources and tools that can significantly reduce existing information constraints.

The proposed framework builds on the seminal model by Parker et al. (1999), renowned for its straightforward yet effective approach to quantifying NIS impacts in marine ecosystems. The ecological impact (I) is expressed as the product of a NIS's distribution range (R), abundance (A), and per capita effect (E): $I = R \times A \times E$. Kotta et al. (2024) provide a detailed explanation of how these equation components can be calculated and offer practical approaches for data collection and analysis. In brief, systematic reviews and meta-analyses are employed to assess per capita impacts, while species distribution modeling (SDM) methods are used to predict the presence of NIS in the area of interest. Additionally, the framework demonstrates how to calculate the uncertainty of impacts at various stages of analysis.

The framework can be applied across five levels of data availability (Fig. 1):

(A) **Data-rich scenario:** Comprehensive quantitative data on NIS impacts (e.g., Hedges' g) and seamless NIS abundance maps allow for the integration of meta-analysis with species distribution modeling, providing spatially explicit evidence of impacts. This involves multiplying the per capita effect size by normalized species abundances or, if abundance data is unavailable, by the probability of occurrence.

(B) **Data-limited scenario (lack of impact information):** Seamless NIS abundance maps are available, but expert judgment is required to assess the per capita effect of NIS. Here, experts estimate the expected magnitude of change in nature value to calculate Hedges' g.

(C) **Data-limited scenario (absence of seamless NIS maps):** Quantitative impact data are available, but insufficient distribution data prevent the creation of abundance maps. The per capita effect size is multiplied by average abundance across the area, assuming no spatial variability in NIS impacts.

(D) Data-poor scenario: Both seamless NIS abundance maps and impact data are lacking. Impacts are inferred through expert judgment or by analyzing similar species, using a flexible meta-analysis approach. Average abundance is used, assuming uniform impact due to the lack of distribution data.

(E) No-data scenario: No abundance information or expert judgment is available, often in the case of newly introduced NIS or in remote, under-researched areas.

Below is an example of how a systematic review and meta-analysis can contribute to a general understanding of the expected environmental impact (or effect sizes) of NIS (Fig. 2). When combined with spatial predictions of NIS distribution, this approach leads to a assessment of the overall environmental impact of NIS (Fig. 3).

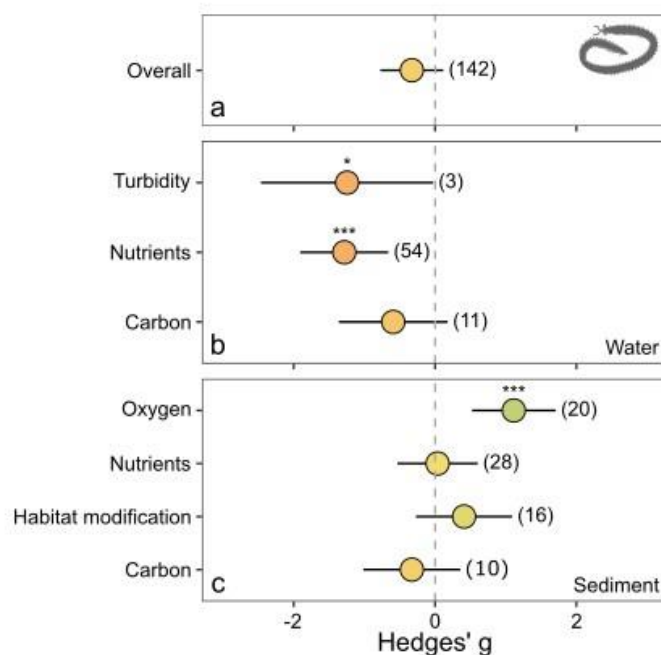


Figure 2. Effects of *Marenzelleria* spp. on abiotic properties and processes in the Baltic Sea. Overall effects resulting from aggregating all gathered evidence (a), and effects on specific properties and processes in the water (b) and sediment (c) are presented. Numbers in between parentheses indicated the respective sample sizes. Whiskers represent the 95% confidence intervals. *p ≤ 0.05, *** p ≤ 0.001.

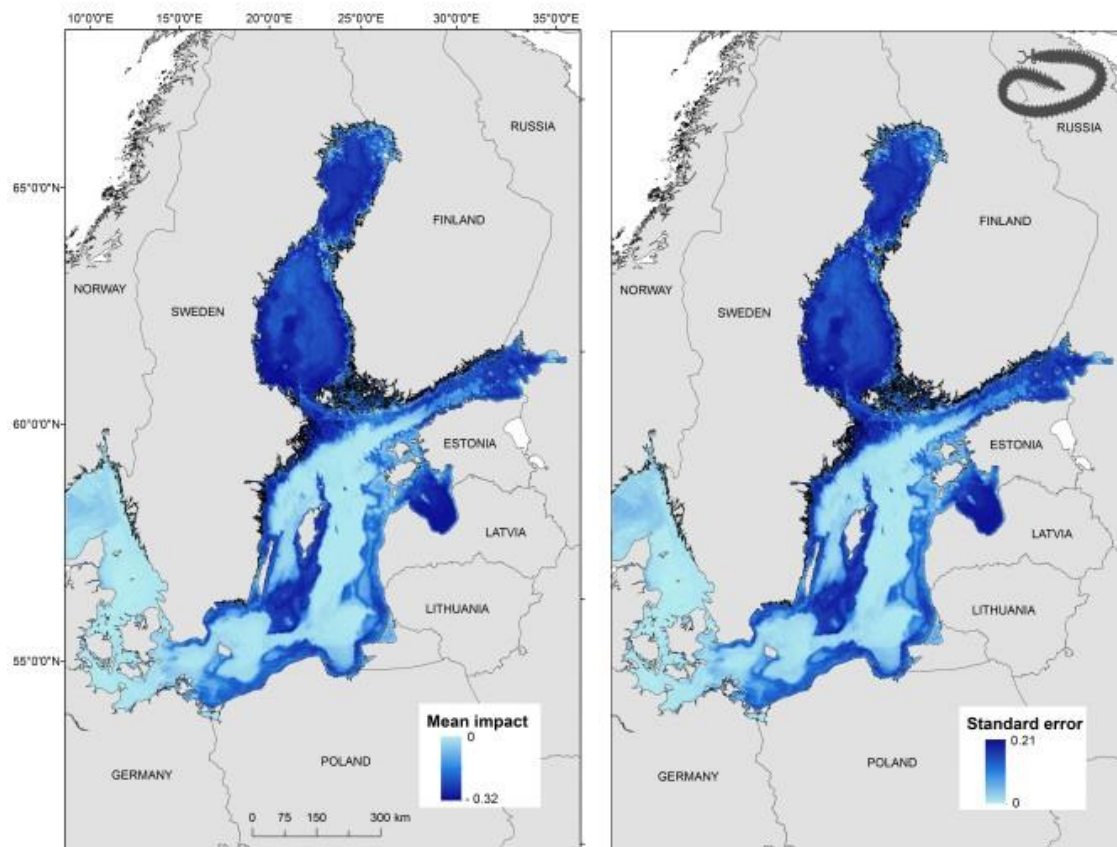


Figure 3. Spatial impact of *Marenzelleria* spp. on the Baltic Sea abiotic environment. Left panel shows the global impact (i.e. the product of the mean effect size and the probability of occurrence, scaled between 0 and 1), providing a detailed view of the impact of the species in different areas. Right panel shows the error propagation calculated using the Taylor series expansion (for more details, refer to Kotta et al. 2024), highlighting the precision and uncertainties in the impact assessment across the region.

Benefits: Although initially more time-consuming, the framework becomes increasingly efficient over time, as the accumulation of distribution data and impact evidence allows for quicker updates to assessments. Moreover, data-driven assessments yield more accurate and objective results, regardless of the experts' backgrounds or numbers. In contrast, expert-based assessments can be biased, particularly when they rely on a limited number of studies conducted in specific contexts. These assessments often overlook crucial contextual details that data-driven methods capture more effectively. While efforts to incorporate contextual details from primary studies and regional data repositories are important, they are better utilized in data-driven methodologies than in subjective scoring systems that broadly categorize impacts into high, medium, or low levels without providing associated confidence values.

Future opportunities: To maximize the management value of the established framework, the information used—such as spatial maps and NIS effect sizes—must be accessible and understandable to a broader audience beyond the scientific community. This requires presenting the data in an easy-to-use format. Digital tools provide a practical solution for simplifying these complex assessments, making them more user-friendly for environmental managers. Web-based tools like PlanWise4Blue play a crucial role in this effort (Kotta et al., 2020;

<https://gis.sea.ee/bluebiosites/>). PlanWise4Blue links NIS distribution maps with their predicted impacts on various nature values using a meta-analytic approach, enabling comprehensive spatial assessments of environmental impacts in a region. Once the tool has been updated with relevant knowledge and data on all NIS in the region, it can be utilized to assess the environmental impacts of NIS, such as through the HELCOM HOLAS assessment.