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Understanding public perceptions of marine threats: awareness and concern among residents and visitors of the German Baltic Sea Coast

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The ecosystem of the Baltic Sea fulfills important functions for the ecological and socio-economic well-being of its surrounding region and human well-being. However, it faces severe threats from human activities, such as hazardous substances, eutrophication, habitat degradation or overfishing which have led to a concerning ecological state of the basin. Public perceptions can provide valuable insights into promoting behavioral change and support for marine conservation strategies. This study examines public perceptions of environmental threats to the Baltic Sea ecosystem among residents and visitors of the Island of Rügen and the Greifswalder Bodden. Data were collected by employing face-to-face interviews (N = 628). Residents and visitors reported high levels of awareness and concern about ecological threats to the Baltic Sea. Yet, they did not accurately assess the ecosystem's poor condition and most frequently identified highly visible threats such as plastic waste or oil spills. Less perceptible and more complex issues, like climate change, biodiversity loss, heavy metals or noise pollution were mentioned infrequently. Participants' perceptions varied according to their proximity of residence to the coast, age and current engagement in educational contexts. It may be further assumed that media coverage, local historical and socio-economic contexts, as well as various personal and psychological factors, contribute to shaping public understanding. The findings suggest that effective marine conservation in the Baltic Sea region may be strengthened by correcting prevalent misconceptions and promoting comprehensive, evidence-based information that also resonates on an emotional level. To support this, it may be beneficial to actively involve local communities and cultivate deeper, more personal connections between the public and the marine environment.

KEYWORDS

baltic sea, risk perception, public opinion, threat awareness, ocean literacy, marine conservation, science communication, ocean governance

1 Introduction

The Baltic Sea is one of the world's largest brackish water bodies (Snoeijs-Leijonmalm et al., 2017; Swain, 2017). Its ecosystem functions are of ecological, economic and cultural importance with an essential role to human well-being (Inácio et al., 2020; Heckwolf et al., 2021). Covering approximately 420,000 km² and bordered by nine nations, its semi-enclosed nature and limited water exchange with the North Sea make it particularly vulnerable to human-induced pressures (Naush et al., 2008; Leppäranta and Myrberg, 2009). The combination of dense population, intensive agriculture, and industrial activity in the surrounding catchment area has led to severe environmental degradation (Szymczycha et al., 2019; Reckermann et al., 2022). Over the years, climate change, pollution from industrial and agricultural runoff, marine litter, and habitat degradation have increasingly threatened its ecological balance, resulting in declining water quality, loss of biodiversity, and the disruption of vital ecosystem services (Reusch et al., 2018; Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV), 2024; HELCOM, 2023a). According to HELCOM (2023a), an intergovernmental organization entrusted with the protection of the Baltic Sea's environmental integrity, the most pressing threats to the Baltic Sea's environmental health are eutrophication, pollution from hazardous substances, and overfishing, in addition to various other pressures. These challenges are further exacerbated by climate change and biodiversity loss. With the anticipated intensification of climate change impacts, it is increasingly crucial to enhance ecosystem resilience and mitigate negative effects, calling for transformative changes across all socioeconomic sectors that influence the Baltic Sea environment (HELCOM, 2023a).

Addressing these environmental threats requires effective conservation measures that go beyond regulatory frameworks and technological solutions. Despite the implementation of policies such as the HELCOM Baltic Sea Action Plan, which has been designed to mitigate pollution and protect marine ecosystems, there has been no improvement in the state of the Baltic Sea thus far (HELCOM, 2023a). This highlights the necessity for additional efforts to enhance the effectiveness of conservation strategies (HELCOM, 2023a). Marine environment management is a complex challenge that demands the creation of integrated conservation strategies grounded in interdisciplinary science, public engagement, and community perspectives (Carpenter et al., 2018; Gkargkavouzi et al., 2019). Scientific insight is vital, not only for deepening ecological understanding but also for examining the social and behavioral factors that impact marine conservation (Gkargkavouzi et al., 2020). Human perceptions of environmental issues are pivotal in this regard, as they can influence attitudes, behaviors, and the development of conservation management or policies (Gelcich and O'Keeffe, 2016; Lacroix et al., 2016; Potts et al., 2016).

One important yet understudied aspect is the public perception of marine pollution in the Baltic Sea. Understanding how different population groups, such as residents and tourists, perceive environmental issues can provide valuable insights into their level

of awareness and concern, with potential implications for conservation efforts (Jefferson et al., 2015; Lotze et al., 2018). Jefferson et al. (2021) posit that research on public perceptions of ocean issues will benefit from a focus on coastal residents and tourists, as these stakeholders have direct interactions with marine ecosystems. Given the economic and recreational significance of coastal areas, these insights may be essential for designing targeted communication strategies and policy measures that foster public engagement and compliance with marine protection initiatives.

Despite the growing recognition of the significance of public perceptions in the context of marine conservation, research in this area remains limited with regard to the Baltic Sea. In light of the acknowledged existence of geographical variations in perceptions of the marine environment, Lucrezi (2022) proposes that national-level studies are valuable for capturing societal perceptions across different scales. Research into public perceptions of marine environments and their threats has been conducted in a number of other European marine regions so far (Gelcich et al., 2014; Potts et al., 2016; Buckley et al., 2017; Lotze et al., 2018; Gkargkavouzi et al., 2020; Lucrezi, 2022; Garcia-Bustos, 2025). However, to date, there has been a lack of research into how the public in the Baltic Sea region perceives threats to the Baltic Sea marine environment. This study aims to fill this gap by investigating public perceptions and concern regarding environmental threats to the Baltic Sea ecosystem among residents and tourists of the Island of Rügen and the Greifswalder Bodden. The study's findings contribute to a more comprehensive understanding of human-environment interactions in a local context and offer insights that can inform the development of more effective conservation policies and public engagement strategies.

2 Theoretical background

2.1 Threats to the ecological system of the Baltic Sea

The Baltic Sea is uniquely vulnerable to environmental pressures due to its semi-enclosed character and slow water renewal over 30–40 years (Stigebrandt, 2001; Snoeijs-Leijonmalm et al., 2017; Reckermann et al., 2022). This prolongs the circulation of discharged nutrients and toxins, increasing the system's susceptibility to contamination and eutrophication. The ecosystem is increasingly impacted by climate change, biodiversity loss, and other anthropogenic stressors, including eutrophication, pollution, habitat degradation, and resource exploitation such as overfishing (Reusch et al., 2018; Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV), 2024; HELCOM, 2023a).

Eutrophication is one of the most severe and persistent problems in the Baltic Sea (HELCOM, 2023a). It is driven by excessive inputs of nitrogen and phosphorus, primarily from agriculture, industrial discharges, wastewater, and ship emissions, via atmospheric deposition and riverine inputs (Gustafsson et al., 2012; Murray et al., 2019; Bundesministerium für Umwelt,

Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV), 2024). These nutrient loads promote phytoplankton blooms, leading to hypoxia and altered community structure (Carstensen et al., 2014; Reckermann et al., 2022). Resulting conditions disrupt benthic habitats and food web dynamics, contributing to biodiversity loss and long-term ecosystem degradation (Conley et al., 2011; Carstensen et al., 2014). The fastest expanding hypoxic and anoxic zones in the world are currently in the Baltic Sea (Carstensen et al., 2014; Breitburg et al., 2018). However, the severity and ecological consequences of eutrophication vary across the basin. Open-sea and northern basins are most affected by oxygen depletion and pelagic nutrient enrichment (Andersen et al., 2011; Ranft et al., 2011; Feistel et al., 2016). The Arkona Basin, including waters around the Island of Rügen and the Greifswalder Bodden, shows moderate eutrophication, with critical nutrient reduction targets still unmet (HELCOM, 2023a). Prolonged nutrient inputs in this region have contributed to a widespread loss of submerged vegetation and a transition to phytoplankton-dominated ecosystems, particularly in the southwestern Baltic Sea (Kanstinger et al., 2018). In summers, cyanobacterial blooms have heavily polluted bathing waters and beaches along the Baltic Sea coast, with some toxin-producing species posing health risks to humans and occasionally leading to dog fatalities (Simola et al., 2011; Bates, 2021; Karlson et al., 2021).

Another major environmental pressure in the Baltic Sea is pollution from hazardous substances (HELCOM, 2023a). Contaminants such as PBDEs, mercury, TBT, copper, and emerging substances like PFAS enter through wastewater, industrial effluents, rivers, atmospheric deposition, and maritime activities (de Wit et al., 2020; Dobrzycka-Kraheil and Bogalecka, 2022; HELCOM, 2023a). These substances are persistent, bio accumulative, and toxic, posing particular risks to top predators such as seals, porpoises, and sea eagles, where they are linked to reproductive failure and population impacts (Dietz et al., 2021; HELCOM, 2023a). The pollution status of the Baltic Sea has remained above acceptable environmental thresholds between 2016 and 2021, including in the Arkona Basin and adjacent coastal waters around Rügen and the Greifswalder Bodden (HELCOM, 2023a). One prominent example of hazardous materials is marine debris, particularly plastics and microplastics. A study conducted in 2017 revealed that beaches on the Island of Rügen exhibited among the highest macro litter levels in the Baltic Sea, with plastics constituting over 80% of the total beach litter (Hengstmann et al., 2017). Microplastic contamination, recognized as a widespread pollutant in the marine food web, is particularly pervasive along the German Baltic coast, primarily originating from wastewater and coastal activities (Stolte et al., 2015). Another risk is contamination from corroding military munitions from military activities and dumping in the western Baltic Sea, a recognized global hotspot (Beck et al., 2019). TNT leakage near the German coast poses a serious environmental hazard, which climate change may worsen by accelerating corrosion and toxin release (Beck et al., 2019; Scharsack et al., 2021; Kammann et al., 2025).

The ecosystem is further put under pressure by commercial fisheries. Overfishing has led to sharp declines in the populations of key species such as cod and herring, undermining both ecological balance and the long-term viability of fisheries (Scotti et al., 2022). These declines are compounded by eutrophication and climate-induced stress, which impair spawning conditions, particularly for species needing oxygen-rich waters (Reckermann et al., 2022; HELCOM, 2023a). Bottom trawling further exacerbates these pressures by physically disturbing benthic habitats, reducing structural complexity, and altering communities of vegetation and invertebrates (ICES, 2024). Coastal areas, including the Island of Rügen and the Greifswalder Bodden, are particularly affected by cumulative human impacts (Korpinen et al., 2012; Elmgren et al., 2015). Throughout the 20th century, intensive trawling, nutrient loading, and land-use changes in adjacent catchments led to submerged vegetation loss and shifts in species composition (Gibson et al., 2007; Olsen et al., 2007). In the Greifswalder Bodden, agriculture and urban development until the 1990s caused vegetation decline and a resulting phytoplankton dominance, leading to the loss of critical spawning and nursery areas for fish (Munkes, 2005; Kanstinger et al., 2018).

Beyond eutrophication, pollution, and overfishing, other anthropogenic pressures are intensifying. Underwater noise has increased significantly due to offshore wind farm constructing, shipping, and piling (Korpinen et al., 2012; HELCOM, 2023a). The introduction of non-indigenous species via maritime transport continues to pose a growing threat, with full ecological implications still unclear (HELCOM, 2023a). Coastal infrastructure, dredging, and bottom-contact fishing disturb sediment and benthic ecosystems, preventing the achievement of good environmental status in all assessed benthic habitats (HELCOM, 2023a).

The cumulative effects of multiple stressors have severely degraded ecosystem quality and biodiversity across the Baltic Sea, disrupting food webs and reducing ecological functioning across trophic levels (Törnroos et al., 2019; Pecuchet et al., 2020; Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV), 2024; HELCOM, 2023a). Although the entire sea is affected, stressor types and impacts vary regionally. Northern basins such as the Bothnian Bay and Sea are most affected by hypoxia and nutrient enrichment but experience lower overall ecosystem service impact. In contrast, southern and southwestern basins, particularly the Arkona Basin, including the Island of Rügen, and the Greifswalder Bodden, face a disproportionate concentration of human impacts (HELCOM, 2023a). According to the Baltic Sea Impact Index (2006–2021), the Arkona Basin ranks among the most severely affected areas per square kilometer, especially regarding impacts on ecosystem services (HELCOM, 2023a).

In this region, multiple pressures converge: bottom trawling, offshore wind energy, and seabed extraction occur alongside elevated atmospheric nitrogen and heavy metal deposition. These are further intensified by land-based sources such as riverine inputs, municipal and industrial wastewater discharges, thermal effluents

from power plants, extensive tourism, and dense coastal infrastructure (HELCOM, 2023a; Korpinen et al., 2012). Climate change further amplifies these pressures by increasing sea surface temperatures, sea level rise, and oxygen depletion. These changes affect pollutant mobility, species distributions, and food web dynamics (Meier et al., 2022; HELCOM, 2023a). Their effects vary across sub-basins and interact with existing stressors, creating complex feedback loops that complicate causal attribution (Meier et al., 2022). Addressing these challenges requires integrated, basin-wide strategies to reduce cumulative pressures and strengthen the Baltic Sea ecosystem's resilience.

2.2 Threat perception

In order to formulate effective conservation strategies, to encourage public participation, and to ensure that scientific knowledge is aligned with societal concerns, it is essential to understand public perceptions of marine environmental threats. While research on public perceptions of marine issues remains relatively limited, an increasing number of studies highlight the complex and sometimes inconsistent ways in which people perceive threats to marine ecosystems (Lucrezi, 2022). These perceptions are shaped by a range of factors, including direct experiences, media coverage, socio-economic contexts, and cultural values (Jefferson et al., 2015, 2021).

A consistent finding across all studies is that pollution, particularly from industrial sources and plastic litter, is the most frequently identified and most concerning marine threat to the European public (Gelcich et al., 2014; Potts et al., 2016; Buckley et al., 2017; Lotze et al., 2018; Gkargkavouzi et al., 2020; Lucrezi, 2022; Garcia-Bustos, 2025). In a global study utilizing surveys and literature reviews, Lotze et al. (2018) found that pollution is also considered the most pressing threat to the marine environment by

the international public, followed by fishing, habitat alteration, climate change, and biodiversity (Lotze et al., 2018).

Despite its profound long-term consequences for marine ecosystems, climate change is consistently perceived as a minor or even negligible threat in many studies. While Lotze et al. (2018) identified climate change among the top five global marine threats, other studies indicate a gap between scientific urgency and public concern (Potts et al., 2016; Gkargkavouzi et al., 2020; Lucrezi, 2022; Garcia-Bustos, 2025). In Italy, for instance, only 23% of respondents in Lucrezi's (2022) study considered climate change a major threat, ranking it far below pollution and litter. Similarly, Garcia-Bustos (2025) found that in Spain, climate change ranked fourth (7.19%), well behind pollution and overfishing.

While pollution remains the predominant concern across studies, regional variations in the prioritization of other threats suggest that local socio-economic and ecological factors play a crucial role in shaping public perceptions. For example, research in Mediterranean regions, such as Greece and Italy, indicates a heightened awareness of specific threats like jellyfish blooms, invasive species, and rising sea temperatures, likely due to their direct impact on tourism and fisheries (Buckley et al., 2017; Lucrezi, 2022). In contrast, in Germany, where industrial activities and offshore energy infrastructure are prominent, public concern is more focused on pollution from industry (Potts et al., 2016). Table 1 provides an overview of the studies that have been conducted on European public perceptions of marine environments, illustrating both the similarities and differences observed across different national contexts. Moreover, research findings indicate that coastal populations generally exhibit higher levels of awareness and concern regarding marine environmental issues when compared with inland residents (Buckley et al., 2017; Lucrezi, 2022). This geographic divide highlights the role of personal experience and place attachment in shaping environmental awareness, as individuals who directly interact with marine

TABLE 1 Overview of findings from European public perception research for marine environments.

Authors	Year	Country/Region	Identified Threats	Question Formats
Gelcich et al. (2014)	2014	EU	pollution (33%), overfishing (8%), coastal erosion (5%), wildlife conservation (5%), and climate change (4%)	Open-ended Question
Potts et al. (2016)	2016	EU	industrial pollution, litter, fishing, and climate change	Likert-Scale Items
		Germany	pollution from industry (4.1), litter (4.0), oil and gas extraction (4.0), climate change (3.7), fisheries (3.6)	5-Point Likert-Scale Items
Buckley et al. (2017)	2017	EU	pollution, over-fishing and habitat destruction	Open-ended Question
Gkargkavouzi et al. (2020)	2020	Greece	litter (96.8%), pollution from industry (94.5%), shipping (57.2%) fishing (53%), farming (50.3%), habitat alteration (34.3%) and climate change (32.3%)	Likert-Scale Items
Lucrezi (2022)	2022	Italy	pollution (air, water, oil) (84%), litter (plastics) (67%), overfishing (26%), climate change (23%)	Open-ended Question
Garcia-Bustos (2025)	2025	Spain	pollution (41.83%), overfishing (37.58%), habitat degradation (12.09%), climate change (7.19%), invasive species (1.31%)	Likert-Scale Items

environments seem to be more likely to recognize and prioritize related threats (Gkargkavouzi et al., 2020).

3 Materials and methods

To investigate public perceptions and concerns regarding environmental threats to the Baltic Sea ecosystem among residents and tourists on the Island of Ruegen and in the Greifswalder Bodden, face-to-face interviews were conducted. These interviews took place at the Baltic Sea between August 3 and September 10, 2024. The sample consisted of coastal recreational users who resided and visited the Island of Ruegen and the Greifswalder Bodden. Participants were recruited using convenience sampling, with a minimum age requirement of 18 years. In total, 628 individuals participated in the survey ($N = 628$), of whom 621 completed the questionnaire in full. The interviews were carried out in various public locations, such as town centers, marketplaces, parks, beaches, and harbors, with an average duration of 19 minutes. The interviews were conducted in German by ten interviewers who documented non-verbal cues and contextual details both during and immediately after the interviews. All interviews were conducted individually, with no grouped interviews included.

The structured questionnaire employed in this study focused on an examination of threat perception. The assessment of this concept involved the utilization of four items. All items refer to the entire ecosystem of the Baltic Sea, not merely the surrounding geographical area of the Island of Ruegen and the Greifswalder Bodden. As the ecological challenges of this marine system are interlinked, an isolated assessment was considered not feasible. The first item evaluated the participants' assessment of the overall ecological state of the Baltic Sea's marine environment on a 6-point Likert scale. The second item was a dichotomous question, with participants indicating whether they were aware of threats to the Baltic Sea (yes/no). The third item employed a 6-point Likert scale to assess the respective concern about the threats that participants were aware of. The fourth item employed an open-format approach to identify the types of threats that the participants expressed concern about. The open-ended format allowed participants to express their perceptions freely without any bias, revealing nuanced and unexpected patterns about perceived threats to the marine environment of the Baltic Sea. The final section of the questionnaire contained questions regarding sociodemographic variables, including age, gender, place of residence, state of origin, and the highest level of education attained.

The data were analyzed using MAXQDA 24 and SPSS version 30. To examine participants' evaluation of the ecological condition of the Baltic Sea, their threat awareness, concern, and sociodemographic distribution, frequency analyses and descriptive statistics were conducted, providing an overview of the variable and participant characteristics. In order to assess the distribution of the variables in relation to the sociodemographic variables, chi-square tests were used for nominal variables. Additionally, Kruskal-Wallis

H tests and Mann-Whitney U tests were applied to compare differences in the continuous variable between the groups. All tests were performed at a significance level of 0.05. To analyze the open-ended question regarding identification of threats, an inductive content analysis was applied to categorize the different types of threats mentioned. Only participants who had previously indicated their awareness of the threats were included in the subsequent analysis ($N = 524$). Respondents' answers were subjected to coding and subsequently collated into subcategories, according to participants' answers. These subcategories were then aggregated into the overall categories of threats identified. Since multiple responses were possible within a single statement, distinct mentions were coded separately. For example, if a participant referred to waste, microplastics, and plastics, the response was coded as waste (1), microplastics (1), and plastics (1) accordingly.

4 Results

4.1 Sociodemographic characteristics of the sample

The participants of the study exhibited a socio-demographic profile that was characterized by a slight over-representation of visitors (56.7%) in comparison to other residency groups, a phenomenon that aligns with seasonal trends that were evident during the summer months. The sample demonstrated a balanced gender distribution, and the age distribution was found to be relatively young, with 47.8% of participants being under 40 years of age. The majority of respondents possessed either a vocational training degree (32.5%) or university degree qualifications (36.9%), suggesting an average to high level of education. The geographical distribution of the participants reflects the study's geographical focus. Participants from Mecklenburg-Vorpommern comprised the majority of the federal state representation (43.8%), followed by more proximate states like Berlin and Brandenburg. This suggests a regional accessibility bias in the sample toward this particular region. The comprehensive overview of all sociodemographic characteristics is presented in Table 2.

4.2 Awareness and concern of environmental threats in the Baltic Sea

Overall, both residents and visitors of the Island of Ruegen and the Greifswalder Bodden exhibited a high level of awareness regarding environmental threats to the Baltic Sea. A substantial majority of respondents (83.4%) reported being aware of threats affecting the sea.

When controlling for sociodemographic variables, chi-square tests of independence (Table 3) revealed statistically significant differences in awareness based on residency status ($\chi^2(1, N = 580) = 6.64, p = .010$) and federal state of origin within Germany ($\chi^2(16, N = 625) = 42.38, p < .001$). Cross-tabulation analysis showed that a

TABLE 2 Sociodemographic characteristics of the sample.

Baseline characteristic	Full sample	
	<i>N</i>	%
Residency	627	100
Visitors	356	56.7
Residents	226	36.0
Working	36	5.7
Others	9	1.4
Missing	1	0.2
Gender	624	100
Female	249	55.6
Male	270	43.0
Diverse	3	0.5
Missing	6	0.9
Age	624	100
18-29	213	33.9
30-39	87	13.9
40-49	86	13.7
50-59	112	17.8
60-69	85	13.5
70-79	29	4.6
80-89	12	1.9
Missing	4	0.6
Education	624	100
No school / still in school	4	0.6
Lower secondary school	44	7.0
University entrance	95	15.1
Vocational training	204	32.5
Still studying	38	6.1
Undergraduate degree	54	8.6
Graduate degree	166	26.4
Doctorate	12	1.9
Other	7	1.1
Missing	4	0.6
State of Origin	627	100
Baden-Württemberg	29	4.6
Bayern	31	4.9
Berlin	61	9.7
Brandenburg	46	7.3
Bremen	3	0.5

(Continued)

TABLE 2 Continued

Baseline characteristic	Full sample	
	<i>N</i>	%
Hamburg	9	1.4
Hessen	20	3.2
Mecklenburg-Vorpommern	275	43.8
Niedersachsen	27	4.3
Nordrhein-Westfalen	41	6.5
Rheinland-Pfalz	10	1.6
Saarland	2	0.3
Sachsen	25	4.0
Sachsen-Anhalt	8	1.3
Schleswig-Holstein	11	1.8
Thüringen	10	1.6
Other Country	19	3.0
Missing	1	0.2

greater proportion of visitors (72.9%) reported unawareness of threats, whereas residents were more likely to report awareness (58.9%). A detailed breakdown of awareness by federal state revealed that respondents from Mecklenburg-Vorpommern, the state where the study area is located, had the highest proportion of self-reported awareness, with 46.9% of all residents (*N* = 274) of this state stating to be aware. In contrast, awareness was significantly lower in states such as Bremen (0.4%, *N* = 2) and Saarland (0.2%, *N* = 3), where only a small proportion of residents reported being aware. However, the robustness of these results may be compromised by disproportional representation, as nearly half of the states had expected frequencies below five, potentially violating assumptions of the chi-square test. Nevertheless, the findings indicate that individuals residing in or near the Baltic Sea, particularly in Mecklenburg-Vorpommern, are significantly more aware of environmental issues, suggesting that geographical proximity and residency are key factors in awareness of threats to the Baltic Sea.

TABLE 3 Results of chi-square tests of independence comparing threat awareness across sociodemographic variables.

Variable	<i>N</i>	<i>df</i>	χ^2	<i>p</i>
Residency	580	1	6.64	.010
Gender	622	3	1.10	.777
Age	622	6	5.10	.531
Education	622	8	2.44	.964
State of Origin	625	16	42.38	.001

p two-sided.

TABLE 4 Results of Mann–Whitney *U* tests comparing threat concern and perceived ecological condition by residency status. Note. *p* two-sided.

Variable	Visitor		Residents		U	z	p
	<i>n</i>	Mean Rank	<i>n</i>	Mean Rank			
Threat Concern	290	248.63	291	243.45	28673.0	-0.41	.679
Ecological Condition	322	282.41	214	247.57	29975.0	-2.67	.008

Consistent with the elevated levels of awareness, respondents exhibited significant concern regarding the threats to the Baltic Sea ($M = 4.65$ on a 6-point Likert scale). A majority of respondents (53.8%) expressed a high level of concern, while only 5.6% reported little to no concern.

Among sociodemographic variables, only the respondent's federal state of origin was significantly associated with differences in concern levels. All test results can be found in [Tables 4, 5](#). A Kruskal–Wallis *H* test showed a statistically significant variation in threat concern scores across the 17 German states, $H(16) = 30.378$, $p = .016$. Descriptive statistics show that respondents from Baden–Württemberg ($M = 5.23$, $SD = 0.86$) expressed the highest concern, followed by Hessen ($M = 5.06$), Hamburg ($M = 5.00$), and Bayern ($M = 5.00$). In contrast, Rheinland–Pfalz ($M = 3.43$, $SD = 1.81$) and Schleswig–Holstein ($M = 3.78$, $SD = 1.39$) reported notably lower levels of concern. Mecklenburg–Vorpommern, the largest group in the sample ($N = 250$), reported a moderate level of concern ($M = 4.64$, $SD = 1.13$), close to the overall mean ($M = 4.65$).

4.3 Assessment of the general ecological condition of the Baltic Sea

Despite the generally high levels of awareness and concern regarding the Baltic Sea, respondents' perceptions of its current ecological condition were moderate ($M = 3.36$ on a 6-point Likert scale). While 21% of participants rated the sea's condition as poor or very poor, 10.1% considered it good or very good. A majority selected mid-range values, suggesting ambivalence or a lack of

specific knowledge, indicative of a central tendency bias in responses.

Analysis of sociodemographic variables revealed that all factors, with the exception of gender, were significantly associated with variations in perception. As demonstrated in [Table 4](#), a Mann–Whitney *U* test showed a statistically significant difference between residents and visitors, $U = 29,975.000$, $z = -2.668$, $p = .008$. Visitors assessed the sea more positively ($M = 3.34$, $SD = 1.06$) compared to residents ($M = 3.09$, $SD = 1.04$), suggesting that proximity may be associated with heightened awareness of local environmental degradation, whereas visitors' assessments may be influenced by more short-term or superficial experiences.

Further analysis using the Kruskal–Wallis test (all results are presented in [Table 5](#)) indicated significant differences across federal states, $H(16) = 42.439$, $p < .001$. Respondents from Mecklenburg–Vorpommern ($N = 263$) reported a below-average evaluation of the environmental condition ($M = 3.09$, $SD = 1.03$), aligning with the general mean score for residents. The most critical evaluations were recorded in Schleswig–Holstein ($M = 2.55$, $SD = 0.82$) and Sachsen–Anhalt ($M = 2.88$, $SD = 0.64$), while the most positive assessments were found in Rheinland–Pfalz ($M = 4.20$, $SD = 1.23$), among international respondents ($M = 4.13$, $SD = 1.41$), and in the Saarland ($M = 4.00$, $N = 1$). The findings reveal significant disparities in environmental perceptions across different regions. A notable observation is that coastal states exhibit a higher prevalence of critical evaluations. In contrast, respondents residing in states that are more distant from the coast demonstrate a more optimistic view. This pattern further supports that physical proximity and direct exposure to environmental stressors may contribute to more negative assessments.

Beyond proximity, age also significantly influenced respondents' evaluations. A Kruskal–Wallis test revealed a significant effect, $H(6) = 21.247$, $p = .002$. Older participants tended to report more favorable views, with the highest mean values observed among the 80–89 ($M = 3.73$, $SD = 0.79$) and 40–49 ($M = 3.56$, $SD = 0.96$) age groups. In contrast, younger respondents aged 18–29 ($M = 3.11$, $SD = 1.00$) and 30–39 ($M = 3.00$, $SD = 1.04$) provided more critical evaluations. These generational differences may reflect divergent access to environmental knowledge, public discourses about environmental issues or the occurrence of environmental issues on political agendas.

Finally, educational attainment was also significantly associated with environmental perception, $H(8) = 19.662$, $p = .012$. Respondents with lower secondary education ($M = 3.51$, $SD = 1.10$) and vocational training ($M = 3.41$, $SD = 1.04$) evaluated the Baltic Sea more positively compared to those currently in education ($M = 2.97$, $SD = 1.11$) or holding university entrance qualifications ($M = 3.00$, $SD = 0.93$). Participants with graduate degrees ($M = 3.22$, $SD = 1.08$) and doctorates ($M = 3.36$, $SD = 1.12$) expressed moderately positive views. This finding suggests a multifaceted relationship between education and environmental perception, wherein individuals who are recently engaged in academic activities may demonstrate heightened environmental awareness and a more critical perspective. This phenomenon may be attributable to present exposure in academic curricula and informal societal dialogues.

TABLE 5 Results of Kruskal–Wallis *H* tests comparing threat concern and perceived ecological condition across sociodemographic variables.

Variable	Threat Concern			Ecological Condition		
	<i>H</i>	<i>df</i>	<i>p</i>	<i>H</i>	<i>df</i>	<i>p</i>
Gender	3.32	3	.346	7.12	3	.068
Age	8.72	6	.190	21.28	6	.002
Education	6.46	8	.594	19.66	8	.012
State of Origin	39.38	16	.016	42.44	16	.001

p two-sided.

Frequencies of Reported Threats to the Baltic Sea Marine Environment (in %)

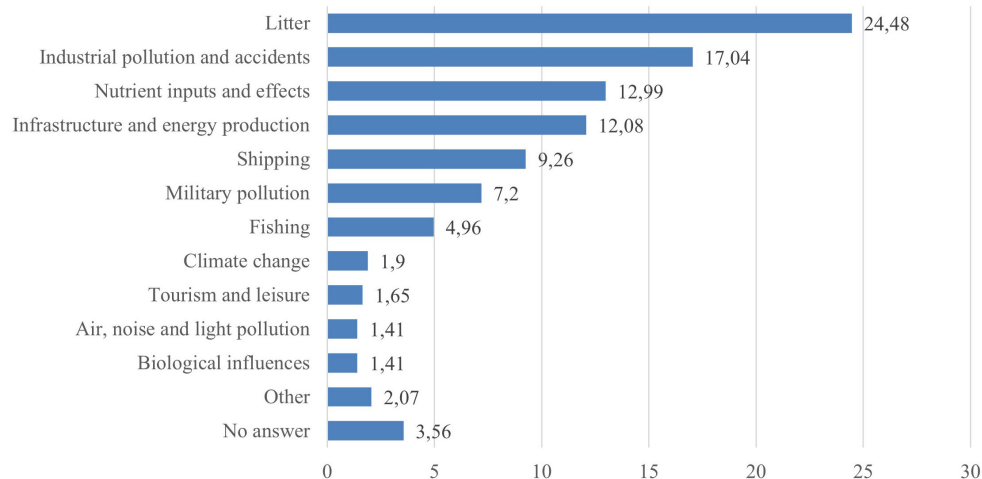


FIGURE 1

Distribution of the frequencies of the types of pollution in the Baltic Sea mentioned by the participants. N = 524.

4.4 Perceptions of environmental threats in the Baltic Sea

A content analysis of participants' open responses provided valuable insights into the specific types of pollution recognized by residents and visitors. Using an inductive categorization approach, thirteen distinct pollution types were identified (Figure 1), with *litter* emerging as the most frequently cited concern (24.5%). Within this category, respondents highlighted the prevalence of plastic waste, both large, visible items and microplastics, as well as concerns about illegal waste disposal and cigarette butts. Following this, albeit at a lower frequency, *industrial pollution and accidents* were reported by 17% of respondents. This category is predominantly concerned with issues such as oil spills resulting from shipping, tank cleaning, and leakage from ageing barrels, as well as the broader environmental impacts of heavy metals, chemicals, and pharmaceutical residues, although these issues are mentioned only sporadically. Similarly, *nutrient inputs and effects* (13.0%) were frequently mentioned, with respondents identifying agricultural runoff, including fertilizers (phosphorus, nitrogen, and nitrates), manure, and sewage, as major contributors. Additionally, references to blue-green algae blooms and oxygen-depleted dead zones underscored the detrimental effects of nutrient overloading in the Baltic Sea. Concerns related to *infrastructure and energy production* (12.0%) were also prominent, with respondents emphasizing the environmental impacts of construction and energy projects, particularly in relation to the LNG (Liquefied Natural Gas) terminal and the Nord Stream pipeline. Additional concerns included offshore wind farms, gas pipelines, and power plants. Less frequently mentioned threats included *shipping* (9.3%), with respondents citing the environmental impact of cruise ships, tankers, cargo ships, and motorboats, as well as ship waste discharge, deteriorating ship parts, and the presence of nuclear

submarines. *Military pollution and historical contaminants* (7.2%) were another concern, with respondents expressing apprehension about the environmental and safety risks posed by unexploded ordnance, war wrecks, and other remnants of past conflicts. Similarly, *fishing* (5.0%) was noted, with particular attention given to ghost nets, discarded fishing gear, and the broader consequences of overfishing. Despite its profound long-term consequences for marine ecosystems, *climate change* impacts were mentioned by only 1.90% of respondents, making it one of the least frequently acknowledged threats. Other rarely cited concerns included *tourism and leisure* (1.7%) and *air, noise, and light pollution* (1.4%), as well as *biological influences* (1.4%), with references to invasive species, bacteria, parasites, and jellyfish. In 3.6% of all mentions, respondents either did not specify a particular type of pollution or expressed uncertainty, despite having previously indicated awareness of pollution. This observation suggests the presence of a small response biases in the response behaviour of the participants.

5 Discussion

This study aimed to explore public perceptions and concerns regarding ecological threats to the Baltic Sea by examining how residents and visitors along the German Baltic Sea coast perceive and assess such threats. While participants reported high levels of awareness and concern, this did not consistently reflect comprehensive ecological understanding. The findings suggest that participants tended to underestimate the poor ecological condition of the Baltic Sea and did not fully grasp the extent of threats facing the ecosystem. Analysis of socio-demographic factors revealed that awareness, concern, and environmental assessments varied significantly depending on proximity to the coast, age, and

educational attainment. Regarding specific threats, participants were most attuned to highly visible and emotionally resonant issues, particularly plastic pollution and oil spills, whereas more complex and less tangible stressors, such as hazardous substances, underwater noise, and climate change, were rarely mentioned. These results reflect broader patterns of the overrepresentation of pollution in public discourse, while also revealing regional particularities, such as notable awareness of munitions dumps and energy infrastructure projects, alongside a low recognition of overfishing.

Waste and industrial pollution, in particular (micro)plastic and oil spills, accounted for over 40% of all threat mentions, aligning with broader European trends in which pollution consistently emerges as the most prominent marine threat (see [Table 1](#)). This heightened salience may be attributed to the concrete and observable nature of these threats, their frequent media portrayal, and their strong emotional impact ([Buckley et al., 2017](#); [Hartley et al., 2018](#); [Lotze et al., 2018](#); [Lucrezi, 2022](#)). Vivid imagery of beaches littered with plastic or dramatic oil spills involving sinking ships may facilitate affective and experiential processing, increasing both cognitive accessibility and emotional engagement. In contrast, less tangible and more complex threats such as climate change (1.9% of mentions), underwater noise (1.41%), and habitat degradation (not mentioned at all) were largely absent from participants' perceptions, mirroring previous findings from other European contexts ([Potts et al., 2016](#); [Gkargkavouzi et al., 2020](#); [Lucrezi, 2022](#); [Garcia-Bustos, 2025](#)). These stressors are typically characterized by spatial and temporal remoteness, diffuse causality, and low visibility, which may collectively limit public engagement and awareness ([Buckley et al., 2017](#); [Lotze et al., 2018](#)). Prior research suggests that such threats are often perceived as abstract, indirect, or outside the sphere of personal responsibility, reducing their potential to trigger emotional concern or moral urgency ([Roeser, 2012](#); [Chilvers et al., 2014](#); [Potts et al., 2016](#)). While the strong public awareness of pollution may illustrate the success of communication strategies targeting these issues, such dominance in discourse may also overshadow ecologically severe but less conspicuous threats. As a result, key challenges like biodiversity loss, persistent organic pollutants, and climate-driven ecosystem transformations risk being underestimated, despite their long-term consequences for marine health ([Easman et al., 2018](#)).

The second most frequently mentioned issue was eutrophication, indicating a growing public awareness of nutrient-related problems in the Baltic Sea. This finding contrasts with earlier European studies, where eutrophication was rarely cited by the public ([Gelcich et al., 2014](#); [Potts et al., 2016](#); [Buckley et al., 2017](#); [Lotze et al., 2018](#); [Lucrezi, 2022](#); [Garcia-Bustos, 2025](#)). One potential explanation for this phenomenon may be the recurrent appearance of cyanobacterial blooms along the German Baltic Sea coast, which have induced public health warnings, particularly concerning risks to dogs ([Karlson et al., 2021](#)). Such events may generate direct experience with eutrophication effects, especially among frequent beach-users. Furthermore, the relatively young and education-engaged sample may have contributed to this heightened awareness, as environmental education and direct interaction

with marine environments are known to correlate with environmental awareness ([Buckley et al., 2017](#); [Lucrezi, 2022](#)). Indeed, in this study, younger participants, which are those currently involved in university education, showed higher awareness and more critical evaluations of the sea's ecological condition. Another explanation may be of a methodological nature. In other studies, eutrophication may have been included in broader categories such as pollution or climate change, thus not representing eutrophication as a discrete issue. Nevertheless, with only 13% of mentions, public attention remains disproportionately low given the scale of its ecological impact ([HELCOM, 2023b](#)). This may again be explained by its less visible, diffuse nature compared to plastic waste or oil spills.

Beyond the issue of visibility, spatial proximity emerged as a factor shaping public perceptions. Participants residing near the Baltic Sea coast were not only more aware of environmental threats, but also more critical in evaluating the sea's ecological condition. In contrast, inland respondents tended to be more optimistic and less informed about ecological risks. These findings echo prior studies highlighting the influence of place attachment and geographical closeness in fostering environmental awareness in marine contexts ([Fauville et al., 2019](#); [Stoll-Kleemann, 2019](#); [Dang and Weiss, 2021](#); [Lucrezi, 2022](#)). Accordingly, coastal residents possess greater exposure to marine environments, enhanced access to region-specific information, and stronger emotional or economic dependencies on the sea. Furthermore, [Rangel et al. \(2015\)](#) argue that coastal users may be more concerned of marine protection, as environmental degradation can threaten their recreational or economic interests. However, this study found no significant difference in environmental concern between coastal residents and visitors with both groups reporting similarly high concern levels. This finding demonstrates that individuals who visit the Baltic Sea coast may also constitute a group of coastal users. Therefore, concern may not only be influenced by long-term connectivity, such as residency, but also by short-term exposure and emotional bonds.

Nevertheless, the findings of this study also demonstrated that despite self-stated awareness and concern, participants did not consistently acknowledge the poor ecological condition of the Baltic Sea ([HELCOM, 2023b](#)). This pattern, also identified in earlier research, reflects a recurring tendency among the general public to underestimate environmental degradation ([Engel et al., 2021](#)). The misalignment may be attributed to a number of factors in addition to those previously discussed. These may include a limited understanding of environmental system dynamics or the ecological state of the Baltic Sea, shaped by unequal access to information, potentially even influenced by socio-demographic factors such as household income ([Lotze et al., 2018](#); [Jefferson et al., 2021](#); [Wootton et al., 2024](#)). Moreover, the process of ecological decline becoming normalized over time may result in distorted reference and judgement bases ([Jefferson et al., 2021](#)). This phenomenon may be further accompanied by psychological variables, such as risk perception, moral disengagement or a sense/lack of moral obligation to engage with environmental issues ([Malka et al., 2009](#); [Gelcich et al., 2014](#); [Stoll-Kleemann, 2019](#)).

Moreover, this study showed that prevailing regional socio-political discourses and temporal factors seemed to have shaped public perceptions. This phenomenon is exemplified by the recurrent references to energy infrastructure projects like the LNG terminal and military contaminants from World War II. The protests against the LNG terminal on the Island of Ruegen, for example, reflected such local concerns, with critics warning of ecological damage to the Baltic Sea, economic risks to the Island's tourism sector, and the project's incompatibility with Germany's climate goals (Deutsche Umwelthilfe e.V., 2024). The protests gained significant media attention at both regional and national levels. Media channels such as *Norddeutscher Rundfunk (NDR)* (NDR, 2024) covered local opposition (as depicted in Figure 2), while *DER SPIEGEL* (2023) and *Tagesschau (ARD-aktuell, 2023)* highlighted broader public resistance, including a petition with 61,000 signatures which was discussed in the German Parliament in May 2023. A comparable dynamic can be observed in relation to corroding military munitions in the Baltic Sea, which were frequently highlighted by participants in this study. The issue may have gained prominence due to its symbolic and emotional resonance, which are associated with war, danger and historical trauma. These associations may evoke stronger affective responses (Xie et al., 2013; Slovic, 2016). Secondly, the visibility of the topic in the public discourse has increased significantly in recent years (Bach et al., 2023). Consequently, the ecological consequences of a toxin release are more immediate and thus more alarming, thereby fostering a sense of urgency and potential for action (Beck et al., 2025). The intersection of contemporary local and national energy debates, economic interests and historical events highlights how past and present challenges can shape public perceptions of threats and their extent and urgency. Overall, such concerns, absent in

previous European studies, highlight the Baltic Sea's distinct historical, political, socio-economic, and environmental context.

Conversely, overfishing, a major concern in Mediterranean studies (Gkargkavouzi et al., 2020; Garcia-Bustos, 2025), was mentioned less frequently. The reasons for this discrepancy can only be assumed. One possible explanation is the marked decline of local small-scale fisheries, which may now be seen as marginal and economically insignificant (Lewin et al., 2023). In addition, the absence of large industrial fisheries in this particular region of the German Baltic Sea may contribute to the fact that overfishing is slightly overlooked in the local discourse (von Thenen et al., 2023; Altmayer and Killmayer, 2025). Finally, fishing may be romantically idealized as part of the region's cultural heritage, fostering a favorable perception that obscures ecological concerns (Inácio et al., 2020). Ultimately, these assumptions require further empirical validation.

While previous research on ocean perceptions has emphasized the influence of multiple factors, including the visibility of environmental impacts, sociodemographic characteristics, and personal experiences (Jefferson et al., 2021; Lucrezi, 2022) this study provides a more nuanced, region-specific perspective for the Baltic Sea. The findings indicate that public perceptions along the German Baltic Sea coast are partly shaped by sociodemographic variables such as place of residence, federal state of origin, age, and educational background. Moreover, the results underscore the substantial role of (in)visibility and the symbolic representation of impacts, most likely mediated by the physical characteristics of threats and the extent of their representation in media and educational contexts. Beyond these factors, the study also highlights the importance of cultural, socio-economic and historic influences, such as traditional fishing, legacies from wartime, and contemporary



FIGURE 2

Citizen protests against the operation of the LNG terminal in Mukran, Ruegen, September 28, 2024. The text on the sign translates to: "Clean gas is a dirty lie!" Photograph taken by the author (2024).

political-economic developments, including the construction of LNG terminals, in shaping how marine environmental threats are perceived in this specific regional context.

5.1 Implications for Ocean communication and Marine conservation

The findings of this study contribute to a more context-sensitive understanding of human–marine interactions along the German Baltic Sea coast, particularly in the regions of Rügen and the Greifswalder Bodden, while offering implications that can extend beyond the local scale. These insights can inform the development of more targeted and effective communication and public engagement strategies for marine conservation (Bennett et al., 2017). By aligning conservation messaging with the specific perceptions and concerns of local stakeholders, such as residents and visitors, efforts to raise awareness and foster behavioral change may become more resonant and impactful (Bennett et al., 2017). In turn, this alignment could enhance both the ecological effectiveness and the support of conservation measures (Jefferson et al., 2021), as previous research has shown that awareness can positively impact behavioral intentions towards environmental protection (Stoll-Kleemann, 2019; Gkargkavouzi et al., 2020; Liu et al., 2021).

5.1.1 Communicating marine environmental threats: emotional framing, media, and public trust

First of all, the findings of this study suggest past and current communication and educational efforts on issues such as pollution seemed to have effectively risen awareness among the public, including residents and visitors on the Island of Rügen and the Greifswalder Bodden. This learning may be leveraged onto raising awareness about environmental threats currently underrepresented, such as diverse other hazardous substances, biodiversity loss, invasive species, habitat destruction, underwater noise and the amplifying systematic threats of climate change. In order to broaden the scope of public marine knowledge and perceptions and ensure a more balanced public understanding, communication and educational campaigns should consider addressing these less visible and complex threats more explicitly by making their impacts more concrete and relatable (Lucrezi, 2022; Umweltbundesamt, 2023). When creating communication efforts for public perceptions and marine conservation strategies, findings of influences from psychological factors such as emotions and trust may help (Stoll-Kleemann et al., 2022; McKinley et al., 2023). For example, narrative-based and emotional communication strategies that features authentic personal stories can help reduce the psychological distance to abstract issues like climate change and foster emotional engagement and compassion for environmental impacts (Markowitz and Shariff, 2012; Roeser, 2012; Stoll-Kleemann et al., 2022). This also aligns with calls from media effects research, which emphasize that the causal links between individual behavior and ecological harm should be made tangible in communication efforts to evoke a moral sense of responsibility

(Markowitz and Shariff, 2012; Stoll-Kleemann et al., 2022). Visual representations of suffering caused by climate change have been shown to increase empathy, especially among skeptics, if they feature credible human subjects rather than abstract imagery (Markowitz and Shariff, 2012). Lucrezi (2022) further suggested showcasing well-known locations and highlighting the environmental threats they face to enhance public awareness and concern about marine environmental issues. For example, the iconic chalk cliffs of Jasmund National Park on Rügen, frequently visited and widely admired, along with the surrounding UNESCO Biosphere Reserve Southeast Rügen, serve as symbols for illustrating the gradual impacts of climate change on coastal environments. By showing how local conservation efforts help protect these unique natural areas from erosion and biodiversity loss, communication can foster a deeper sense of connection and personal agency. Such examples may offer place-based entry points to communicate the tangible impacts of environmental change and link them to local cultural and ecological values.

At the same time, data-heavy, overly complex or fear-based messages may be overwhelming and discourage action (O'Neill and Nicholson-Cole, 2009; Gifford, 2011; Roeser, 2012). Instead, there is evidence on the effects of positive emotional engagement, such as feelings of awe, fascination, and personal relevance, in shaping perceptions, concern and motivating action for ocean health (Balmford et al., 2002; Jefferson et al., 2015; Stoll-Kleemann, 2019; McKinley and Burdon, 2020). To enhance emotional resonance, communication efforts should foster positive emotional connections with the marine environment while also providing clear and empowering recommendations for action (Stoll-Kleemann, 2019). Narratives of hope, small behavioral successes, and solution-focused messages, as exemplified by concepts like “Ocean Optimism” which aims at “spreading good news and conservation success stories through social media channels” (Easman et al., 2018, p.239), can inspire awareness and counteract the paralyzing effects of fear or doom-laden messaging (Easman et al., 2018; Curnock et al., 2019; Lucrezi, 2022). Thus, communication efforts may combine reporting on environmental harm with empowering storytelling that highlight the effectiveness of mitigation strategies and personal agency (Holbert et al., 2003; Roeser, 2012; Chambers et al., 2019; Stoll-Kleemann et al., 2022).

Additionally, media exposure was discussed to shape public threat perceptions, such as in the case of plastic pollution or oil spills. Research indicates that media coverage significantly shapes public discourse and policy-making, yet much of this media coverage often fails to address the more complex and less visible aspects of marine degradation (Boykoff, 2008; Pinto and Matias, 2023). As in previous research, media exposure was found to foster environmental concern, media may also play a vital role in shedding more light on the underrepresented threats or in fostering awareness about the actual poor state of the Baltic Sea (Young et al., 2013; Liu and Li, 2021; Stoll-Kleemann et al., 2022). To enable the media to fulfill this role more effectively, science communication can improve using simplified, audience-specific messaging and interdisciplinary collaboration involving journalism, social-media,

advertising or even event management, which can help produce more impactful content and increase public awareness and engagement (Shove, 2010; Easman et al., 2018).

To reduce polarization and improve the accuracy of public perception, institutionalized collaborations between media outlets, including social media platforms, scientists, and policymakers could be instrumental in promoting evidence-based, balanced communication (Owen et al., 2012). Long-term partnerships may further help to ensure that marine threats, both immediate and gradual, are conveyed accurately, and that misinformation or sensationalism is minimized. Strengthening these collaborations has the potential to not only improve the public's understanding of complex marine threats but also enhance trust in scientific expertise and media coverage (Kaaria, 2025; Mede et al., 2025). Trust, in turn, also plays a crucial role in shaping public attitudes toward marine issues (Gelcich et al., 2014; Chambers et al., 2019; Hofman et al., 2020; Hogg et al., 2021; Liu et al., 2021; Soares et al., 2021). In countries like Germany, where institutional skepticism is high, communication strategies should prioritize transparency, inclusivity, and the active involvement of trusted local actors (Buckley et al., 2017; Stoll-Kleemann et al., 2022). It is therefore essential to adapt and target communication efforts to the information sources and formats that divergent audience groups already trust (Buckley et al., 2017; Gelcich et al., 2014). Multi-stakeholder collaborations between scientists, NGOs, educators, and media professionals can enhance both credibility and public receptiveness by tailoring messages to local concerns and communication channels (Lucrezi, 2022). Ultimately, combining fact-based reporting with trust-building and emotionally resonant storytelling may help to build a socially legitimate, inclusive, and effective marine conservation discourse.

5.1.2 Proximity, experience, and ocean connection: direct and mediated exposures

The findings of this study further emphasize the importance of spatial proximity and educational exposure in shaping public awareness of marine environmental issues along the German Baltic Sea coast. Future communication and conservation strategies could therefore aim to engage geographically and educationally diverse audiences—particularly those who may lack direct access to the ocean or formal education about marine ecosystems. Supporting this, an Australian study on youth suggests that increasing interaction with marine spaces can foster stronger connections to the ocean (Wootton et al., 2024), aligning with broader evidence on the positive impact of marine experiences on ocean-friendly perceptions and behavioral intentions (Rodger and Susan, 2007; Zeppel and Muloin, 2008; García-Cegarra and Pacheco, 2017; Liu et al., 2021; Yoon et al., 2021). In the context of the Baltic Sea, national park authorities, municipalities, NGOs, and tourism providers could offer excursions, sea-related events, or build upon existing marine activities to deliberately foster emotional connections with marine environments. These could be paired with simple, non-overwhelming informational content.

Given that many individuals today are physically and emotionally distanced from the ocean, creating tangible

experiences could be crucial to enhance both understanding and support for conservation (Wootton et al., 2024). For individuals living far from the coast, such exposure could also be facilitated through digital means, such as films, social media content, online exhibitions, or interactive games. Offline options may include mobile exhibitions or small installations in landlocked areas that offer sensory experiences: the sound of waves, the feeling of sand underfoot, or interactions with (animated) marine creatures. Examples of such existing initiatives include the *International Ocean Film Tour*, which screens diverse ocean-related films across cinemas in Europe; the *Oceanspace.org* platform, which curates online and offline ocean-themed art experiences; and exhibitions like *The Cast Whale Project*, a life-size 14-meter whale sculpture by Israeli artist Gil Shachar displayed in a Berlin church (Moving Adventures Medien GmbH; Ocean Space; Shachar,). However, it is imperative that these tangible experiences are adapted to suit various target groups in order to ensure an effectively address people in their respective contexts (Jefferson et al., 2015; Lucrezi, 2022).

5.1.3 Local contexts and participatory approaches: integrating social, cultural, and historical dimensions in marine conservation communication

To enhance the societal relevance and local resonance of marine conservation communication, it may be beneficial to adapt strategies to the specific socio-political, historical, and cultural conditions that shape public perceptions (Jefferson et al., 2015, 2021; Potts et al., 2016). As demonstrated in this study, awareness of marine environmental threats in the Baltic Sea region is not solely shaped by ecological knowledge or spatial proximity, but also by regionally prominent discourses and unfolding political events. For instance, the public controversy surrounding the LNG terminal on the Island of Ruegen and concerns about corroding wartime munitions illustrate how historically and politically charged issues can trigger public engagement and shape perceptions of urgency and risk.

To address this, future communication efforts could benefit from a multi-level approach, as recommended by the German Environmental Agency, that complements broader media campaigns with locally rooted, participatory initiatives (Umweltbundesamt, 2023). Citizen science projects, for instance, may offer opportunities for individuals to become directly involved in marine environmental monitoring, the co-creation of marine knowledge and even marine decision-making processes (Cappelletto et al., 2021). Such engagement has the potential to foster emotional and cognitive connection with the Baltic Sea environment, uncover local concerns, and contribute to the perceived legitimacy and effectiveness of marine governance (Bennett et al., 2017; Burdon et al., 2019; Jefferson et al., 2021).

Moreover, allowing people to relate to marine challenges in ways that reflect their cultural or historical background might enhance their sense of self-efficacy, which in turn could support more enduring behavior change (Chilvers et al., 2014; Lucrezi, 2022). In this context, Schwerdtner Manes et al. (2023) advocate

for the development of regional ocean literacy frameworks that incorporate historical, cultural, and socio-economic dimensions to foster a more nuanced, science-informed understanding of marine issues. Enhancing ocean literacy, defined as the understanding of the reciprocal relationship between humans and the ocean, may facilitate more meaningful engagement and informed decision-making regarding marine environments (Brennan et al., 2019; McKinley et al., 2023; Shellock et al., 2024).

While this study provides valuable insights into public perceptions of marine threats in the Baltic Sea, several avenues for future research remain. First, many of the suggested implications and interventions, such as emotional storytelling, enhancing personal experience with marine environments or local participatory formats require systematic empirical validation (Jefferson et al., 2015; McKinley and Burdon, 2020). Future studies may therefore benefit from moving beyond the traditional focus on knowledge and educational interventions, to empirically assess the psychological and affective dimensions of marine communication. Experimental and longitudinal designs could be particularly useful in evaluating the long-term efficacy of these approaches. Second, the role of media in shaping public perceptions of marine environmental threats warrants closer examination. Despite its attributed relevance, research on the representation of marine threats across various media formats, particularly social and regional media, remains limited (Pinto and Matias, 2023). Thus, future work could explore how different framing strategies influence public understanding, urgency, or perceived credibility, ideally through large-scale comparative studies across the Baltic Sea region.

Additionally, comparative research could provide critical insights into how local socio-economic conditions, historical experiences, and cultural narratives influence public interpretation of marine threats. The diversity of coastal communities along the Baltic Sea presents a unique opportunity to examine regional variation in perception and response. Such studies could help to disentangle the relative influence of proximity, historical symbolism (e.g., war munitions), and current political discourse (e.g., energy infrastructure) on threat perception and marine environmental concern.

Finally, future investigations may also empirically explore a variety of other factors that affect marine public perceptions, such as emotions, trust or risk perception. This would not only deepen theoretical understanding of marine perception but also offer practical guidance for designing context-sensitive, inclusive, and socially legitimate conservation communication strategies with applicability far beyond the Baltic Sea.

Taken together, these insights suggest that communication strategies in the Baltic Sea region may benefit from moving beyond generalized awareness raising communication campaigns. Combining comprehensive information with solution-oriented, emotionally engaging narratives that are locally embedded, participatory and tangible even beyond coastlines could play a key role in fostering trust, increasing factual awareness beyond visible threats and may even promote behavior change and support for marine conservation action at the German Baltic Sea coast.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by University of Greifswald, Ethikkommission Universitätsmedizin Greifswald. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RD: Conceptualization, Writing – original draft, Visualization, Software, Methodology, Data curation, Investigation, Writing – review & editing. SS: Investigation, Writing – review & editing, Methodology, Validation, Funding acquisition, Resources, Project administration, Supervision, Visualization, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2025.1596331/full#supplementary-material>

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