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Research article

Perception of climate change impacts, urbanization, and coastal planning in the Gaeta Gulf (central Tyrrhenian Sea): A multidimensional approach

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Abstract: The coasts, with their intricate combination of natural and anthropogenic fragilities, can always be considered a crucial component in the geography of risk and territorial governance. Furthermore, coastal areas worldwide are currently facing profound and immediate impacts of climate change, presenting unparalleled challenges for both ecosystems and coastal communities. In these contexts, high socio-environmental vulnerability has often been linked to planning and management practices that, at times, have exacerbated coastal exposure, making it more prone to extreme natural phenomena, such as coastal floods and storm surges, as well as degradation. The case of the Gaeta Gulf, a largely urbanized part of the central Tyrrhenian coast in Italy that encompasses two administrative areas between the northern Campania and the southern Lazio Regions, provides an opportunity to investigate these criticalities both along the coastline and within the interconnected inland areas. This research aims to understand how administrations and communities perceive, experience, and understand the coastal risks and challenges posed by climate change, as well as their level of information and preparedness to address such risks. These aspects will be analyzed through a multidisciplinary approach, shedding light on the political, social, environmental, and economic practices in these areas, and the potential implications for coastal planning policies. In addition, this contribution presents the results of a qualitative survey involving the administration of questionnaires related to the perception of climate change impacts on the coasts and the level of information on the mitigation and adaptation practices within the communities living in these areas.

Keywords: coastal risk; risk perception; coastal planning; climate change; Gaeta Gulf; Italy

1. Introduction

The international scientific community has now consolidated the notion that the planet's climate is undergoing profound changes with non-uniform effects in different regions [1]. These climate changes pose a significant threat to coastal areas worldwide, with increasing temperatures, sea-level rise, greater storm intensity, and extreme weather events shaping coastal ecosystems and jeopardizing the livelihoods of millions of people [1]. Sea-level rise is also leading to more pronounced coastal erosion, frequent and severe flooding, and the intrusion of saltwater into freshwater bodies [2]. To fully understand these dynamics and develop effective adaptation strategies, it is essential to analyze not only the physical aspects of the phenomena, but also the risk perception of the communities involved, the decision-making and planning processes within urban contexts in relation to environmental risk, and the communication with the exposed populations, which has significant impacts on their behavior [3,4].

Risk perception is not an objective but a subjective process, influenced by cultural, social, and economic factors, as well as by individual and group values, beliefs, and personal experiences [5–8]. Understanding the probability of the occurrence of a phenomenon and the severity of the related risk are fundamental for motivating the adoption of protective behaviors [9]. Perceived probability refers to the moment in which a person thinks that a certain event will happen without worrying about how this happens or what consequences it may have; perceived severity, on the other hand, consists of attributing a quantification in terms of damage deriving from a specific event. Thus, an event perceived with a high probability of occurrence would translate into weak motivation if not accompanied by an awareness of the harm that event could cause [10]. Indeed, the lack of adequate risk perception can compromise the effectiveness of adaptation measures and the resilience of local communities [11]. Furthermore, institutions and the trust or lack thereof that local populations place in them and other private stakeholders play a fundamental role in influencing the adaptive behaviors of the population, acting as a bridge between the scientific community and citizens, thereby shaping local climate culture [12].

Based on a literature review, it is evident that historical and socio-cultural perspectives play a crucial role not only in risk perception, but also in risk reduction and adaptation strategies [13]. Moreover, involving both stakeholders and end-users of territorial management in the decision-making process opens the possibility of influencing risk perception, i.e., how people evaluate the characteristics and severity of an event, especially for those residing in risk-prone areas [14,15]. This approach would also promote more responsible planning and implementation of risk reduction measures at the local level. In this regard, while it has been noted on one hand that risk perception depends on individual characteristics, the nature of the risk, and the level of trust in institutions [9], what seems to be lacking is an understanding of the effects of the prevailing governance policies (whether they are oriented towards the public or the private sector) on the level of awareness and/or risk perception.

Italy, with its complex physical and geomorphological conformation and due to its location in a climate hotspot of the Mediterranean region, represents an interesting laboratory for the study of risk perception. The country is not homogeneously influenced by climate change, but shows specific territorial variations depending on the climatic variables taken into consideration [16]. For example, rainfall has decreased across the entire national territory, with greater intensity in the central-south

compared to the north [17]. On the other hand, differences in the subsidence of northern regions compared to southern ones will affect sea level rise differently, posing greater risks to the northern coasts [18]. Particularly, coastal areas present extreme complexity and vulnerability as they are transitional zones between the marine and terrestrial systems. Both are simultaneously affected by the alterations of rainfall quantity and distribution during the year, and by the change in the relative sea level. Adding to this complexity is the fact that the Italian coast has experienced an intense increase in urbanization and population concentration over the last century. Nonetheless, many coastal areas are home to cities, towns, and resorts that attract significant tourist flows. However, this intense human presence and associated infrastructure pose challenges in managing the impacts of climate change, making urbanized coastal regions more vulnerable to hazards such as flooding and coastal erosion. In this context, the consequences of the climate crisis could seriously undermine the foundations of a predominantly coastal-based way of life and economy. For this reason, in addressing coastal landscapes, Woodroffe emphasizes a multidimensional vulnerability related to bio-geophysical responses, as well as economic, institutional, and sociocultural aspects [19].

In Italy, the perception of risks related to climate change has been the subject of recent geographical studies [4,20–22]. The perception of risk linked to the climate crisis is complex and varied, with rhetoric that includes the ecologic vision, the catastrophic perspective, and the denial of climate change itself [23,24]. A recent study conducted by Casareale and Gioia (2022) in the Regions of Friuli-Venezia Giulia, Veneto, Marche, and Puglia revealed that the predominant narrative is the catastrophic one, followed by environmentalism, while denial is only present in a small percentage of adult men [25]. This suggests a growing awareness of the climate crisis among citizens, but it is unclear whether they fully understand the risks associated with it.

This study focuses on the coastal area of the Gaeta Gulf, a portion of a largely urbanized territory on the western coast of central Italy, facing the Tyrrhenian Sea and located between the two administrative regions of Lazio and Campania. This area is characterized by unique environmental and cultural aspects, as highlighted in the second paragraph, making it a case study of significant relevance for understanding the challenges associated with the climate crisis. Here, conflicts emerge both in the desire to preserve natural and historical resources, such as through the establishment of parks, and in the inability to plan for growth properly, the result of a rush toward industrialization and chaotic land exploitation. These conflicts have irreparably damaged the quality of the environment and landscapes [26]. The fundamental objective of our research is to analyze the perceptions of climate change-related risks and coastal planning among the population residing in the Gaeta Gulf through field research conducted via questionnaires and semi-structured interviews with key stakeholders. The results will help to identify some of the factors that influence the perception of coastal risk, including the policies implemented (or not, and to what extent) in response to the effects of climate change in the study area. This information will provide a basis for developing proposals that can contribute to more effective local adaptation policies and operational strategies in the context of integrated management.

2. Overview of the study area

Located in the Italian Central Tyrrhenian Sea, the Gaeta Gulf extends in an intricate manner for a length of approximately 150 km, spanning the Regions of Lazio and Campania. It is bounded by the Circeo promontory (San Felice Circeo, LT) to the north and Capo Miseno (Bacoli, NA) to the south (Figure 1).

Figure 1. Location of the research area in Italy, with the principal toponyms. Provincial boundaries are in red; municipal boundaries are in black.

Table 1. Summary table of key data for the 16 municipalities under review.

Region	Province	Municipality	Km^2	Population (2022)
Lazio	*LT*	San Felice Circeo	32,631	10.100
		Terracina	136,588	44.504
		Fondi	143,913	39.507
		Sperlonga	19,49	3.081
		Itri	32,631	10.371
		Gaeta	29,203	19.598
		Formia	143,913	37.278
		Minturno	42,134	20.215
Campania	*CE*	Sessa Aurunca	162,187	20.366
		Cellole	36,781	8.086
		Mondragone	55,726	28.474
		Castel Volturno	73,941	27.804
	NA	Giugliano in Campania	94,632	123.758
		Pozzuoli	43,434	75.952
		Bacoli	13,468	25.410
		Monte di Procida	3,6	12.826

Although the physiographic unit, namely a coastal stretch with sediment transport confined within the unit itself, is officially recognized between Punta Stendardo and Bacoli, it has been decided, for the sake of comprehensiveness, to analyze the Gulf in its current geographical sense, incorporating the municipalities north of Gaeta into the analysis (Table 1). For the same reason, the islands administratively belonging to the municipalities of Ponza, Ventotene (LT), and Procida (NA) will not be considered.

The morphological features of the area are influenced by the mountainous systems of the Aurunci mountain range, Monte Massico, Monti Trebulani, the Roccamonfina Volcano, and the Campi Flegrei, as well as the associated morphostructural depressions primarily filled with volcaniclastic deposits and continental sediment from the Garigliano and Volturno river systems [27]. The coastline, configured into two sub-arches, Capo Circeo-Punta Stendardo and Punta Stendardo-Capo Miseno, is largely characterized by sandy beaches, often featuring relic dune cords (Figure 2). In the area north of the Gaeta isthmus up to Sperlonga, cliffs carved into limestone rocks alternating with mostly sandy pocket beaches can be observed [28]. The geomorphological genesis of the area has also been influenced by the effects of extensive reclamation work carried out over time [29].

Figure 2. Foredune in Castel Volturno (CE) with psammophilic vegetation. This public beach is one of the few areas where this system is in place, as other sections have been flattened by private lido operators or beachfront construction.

Despite conservation efforts, the coastlines of the Gulf have undergone significant modifications due to intensive urbanization and hydraulic works [26,30–32]. These alterations include the Spring of Capo Volturno dam, constructed between 1909 and 1916, and the Ponte Annibale di Capua Weir, built between 1953 and 1958, which can also be linked to intensive agricultural, livestock, and aquaculture practices both in coasts and in catchment areas.

Nevertheless, there was a noticeable increase in shoreline progradation until the 1970s (as evidenced by geo-indicators constructed using historical data, mainly maps and photogrammetry), and a surge in critical issues emerged from this temporal watershed. In addition to the reasons associated with extensive coastal urban development—in terms of urbanization and edification—that further weakened the system by stripping it of its natural defenses (e.g., the disappearance of the coastal dune system due to sand mining, vegetation removal and poor land management practices, and the effects of extreme weather events), there was a clear reduction in sediment input upstream. This reduction primarily results from the extraction of sediments from riverbeds and the construction of hydraulic structures in the backwaters. Furthermore, the devastating impacts of extreme meteorological events,

linked to climate change effects, have become increasingly tangible today [33–36]. Currently, as highlighted by data from the Italian Institute for Environmental Protection and Research (ISPRA), there is a noticeable increase in erosion, leading to a significant retreat of the shoreline everywhere. This retreat has been exacerbated by the presence of linear infrastructures (such as the SS7qtr and SR213 roads and the "Direttissima" Napoli-Roma railway line), as well as a growing number of ports and docks. Despite the existence of 46 defense structures, these measures have contributed to the hardening of the coastal system (Figure 3).

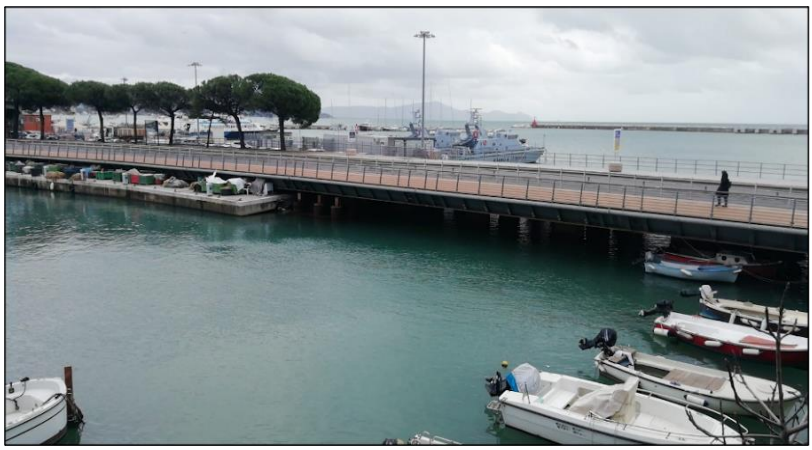

Figure 3. Formia (LT) marina, SR213 dock, and Vespucci harbor.

The Gulf, known for its exceptional fertility due to its volcanic soils, has been inhabited since the Paleolithic era (around 35,000 years ago). It became home to Roman colonies (by 345 bc) and played a significant role, especially during the Angevin and Aragonese dominions (XIV to XVI century) [37]. Subsequently, during the Bourbon period (1734–1861), the Gulf held a prominent political and economic position. Extensive reclamation works were carried out in the hinterland through a complex system of drainage canals [38–40].

Today, it is bordered by sixteen municipalities that result in a built continuum characterized by substantial urban sprawl, spanning the Metropolitan City of Naples and the provinces of Caserta and Latina. The total population stands at approximately 510,000 inhabitants. As can be observed from Table 1, the population is unevenly distributed and is predominantly concentrated in the Campanian portion of the Gulf in both quantity and density. However, this figure does not account for tourism-related pressure, especially during the summer season, which multiplies the population in coastal municipalities, intensifying issues related to the deterioration of water quality and marine ecosystems [41]. It also does not consider the significant unregistered presence of migrant populations residing and working in local production activities, particularly in the primary sector, as well as in the construction and agro-food industries [42–45].

The shoreline of the Gulf, beyond its tourist appeal and the associated issues related to beach concessions, is also a hub for illegal activities, the consequences of which further weaken the region in terms of socio-environmental risks (Figure 4a,b). These include land and marine pollution, degradation caused by waste dumping and submergence, unauthorized construction, land consumption, and sand quarrying, which have led to the formation of a broad succession of contaminated artificial basins [46,47].

Figure 4. a) Rio Acquatraversa, Formia (LT). The stream that flows into the harbor has been regimented and reduced to a dump; b) Varcaturo coastline near Giugliano in Campania (CE) with "ecomonsters" (ugly and environmentally damaging buildings) on the beach.

The outlined framework underscores significant morpho-dynamic issues that, when combined with substantial anthropogenic pressure and the ongoing effects of climate alterations, complicate the Gulf's riskscape. The impacts currently observed, and the potential ones, both in terms of the frequency and intensity of related phenomena, are poised to amplify the underlying socio-environmental vulnerabilities [48]. Consequently, given the cross-border nature of coastal issues and associated risks, with a view towards concrete integrated governance, active involvement of all stakeholders in the region is imperative, as is citizen engagement and awareness. This is crucial to overcome conflicting elements regarding the use of an increasingly scarce resource—the coastline, whose risk perception, as we will see, is influenced by these factors [49,50].

3. The fieldwork

To investigate the population's level of risk perception in the context of climate change, a qualitative, multidimensional research study was conducted. During the period January-May 2023, an online questionnaire was distributed to the population of the 16 municipalities belonging to the Gulf of Gaeta via Google Form. Data collection was carried out by the non-probability snowball sampling method, which involves the initial selection of an individual or group, followed by the collection of additional participants through recommendations or personal connections of those already included in the study. Dissemination was done via e-mail and through major social media, such as Whatsapp and local Facebook groups. This choice may have influenced the type of audience reached by the survey, especially in terms of age and socio-cultural background. Due to the methodologies used, we also acknowledge a strong bias represented by the absence of migrant communities living in these areas, albeit with different degrees of recognition. However, this method has allowed us to obtain a large distribution across all municipalities. Online surveys, in fact, are recognized as a powerful tool for increasing sample size in many survey areas and are becoming increasingly popular in academic research [51,52].

The questionnaire, consisting of a total of 26 questions, was structured into several sections (see Annex 1 in Supplementary Material). The first section is devoted to demographic information, aiming

to profile the participants' demographics through a series of five questions. The second section focuses on perceptions of climate change, aiming to gather information regarding personal knowledge, understanding, and propensity to adapt to climate change: it formulates seven questions for this purpose. The third section examines the perception of climate change within the participants' community of residence, seeking to assess awareness of climate change impacts in this specific area through a set of seven questions. The fourth section, consisting of six questions, focuses on perceptions of local governance and on investigating local actors who should be involved in climate change response actions. Finally, the fifth section provided an opportunity for participants to release additional comments or considerations through a single open-ended question.

The questions were formulated following four different response types:

- Single-choice questions, for which the respondent could express only one choice;
- Multiple-choice questions, for which the respondent could express more than one choice;
- Single-choice questions on a psychometric scale, for which the respondent was required to make a judgment on a "Likert" scale in agreement with a specific statement;
- Open-ended questions, which allowed respondents to provide open comments.

The responses were analyzed using the methodologies of descriptive statistics. Using IBM SPSS Statistics 27 software, contingency tables were constructed to test the degree of association between questions. This technique made it possible to assess the number of responses given by respondents to different combinations of questions and to determine whether these were related to each other. For greater readability in the presentation of results, in Likert-type questions, the responses "Agree" and "Completely Agree", and those "Disagree" and "Completely Disagree" were grouped into "Agree" and "Disagree," respectively.

4. Results and discussions

The results of the survey presented here allow us to enumerate some elements related to the analysis of the perception of climate change-related risks as well as those inherent to coastal planning.

Since it is not possible to analyze all the obtained results for reasons of limited space, we first profile the respondents to the questionnaire and semi-structured interviews on a demographic basis, then we analyze the research results along three main axes: i) the perception of the phenomenon at the global level and its local downsizing, ii) the governance tools put in place by actors—public and/or private—involved in the implementation of measures to counter the impacts of meteoclimatic alterations, and iii) the possible and specific actions to mitigate its effects in the short and medium term; and the possible "transferability" of these tools to other contexts.

A total of 260 online questionnaires were collected, and fifteen semi-structured interviews were conducted, as outlined in the methodological section (§3). The sample of questionnaire respondents, as illustrated by the graphs in Figure 5, shows a slight overrepresentation of the female sex (57%, A). As for the age groups, 43% are between 20 and 39 years old, while 35% are between 40 and 59 years old and 19% are older (B). Therefore, there is a lack of under-19 cohorts, probably related to the difficulty encountered in using communication channels closer to the interests of younger people. For the same reason, and especially because of how the questionnaire was administered (mainly snowball sampling from direct contacts, primarily colleagues, and university students), the data regarding the highest level of education attained is inherently unbalanced, which for the sample is 64% "university" and 32% high school (C).

Despite these biases, it is particularly interesting to note that about 61% of the sample lives within one kilometer of the coast (D). About a quarter of the respondents live even within 200 m, a fact that is extremely relevant for understanding the perception of the phenomenon being surveyed. Indeed, the definition of the coastal strip, at the legal level, indicates the territories included at a distance of 300 meters from the shoreline (Legislative Decree 490/99 and Legislative Decree 42/04, as amended).

Considering the geographic distribution of the questionnaires, the sample shows an equal sharing between residents in Lazio Region (129) and those in Campania Region (108), as shown in Table 2. Even at the municipal level, considering the proportion to the resident population, the participants are evenly distributed. However, an exception is observed for the municipalities of Fondi (Lazio) and Castel Volturno and Giugliano in Campania (Campania).

Table 2. Summary table of the fieldwork carried out by Municipality

Region	Province	Municipality	Interview	Inspections	Survey
Lazio	LT	San Felice al Circeo	1		13
		Terracina			19
		Fondi			9
		Sperlonga			2
		Itri			7
		Gaeta			15
		Formia		X	35
		Minturno	3	X	29
Campania	CE	Sessa Aurunca			14
		Cellole	3	X	9
		Mondragone	4	X	21
		Castel Volturno			4
	NA	Giugliano in Campania	1	X	21
		Pozzuoli	2	X	27
		Bacoli	1	X	12
		Monte di Procida			0
		Prefer not to say	–	–	23
		Total	15	7	260

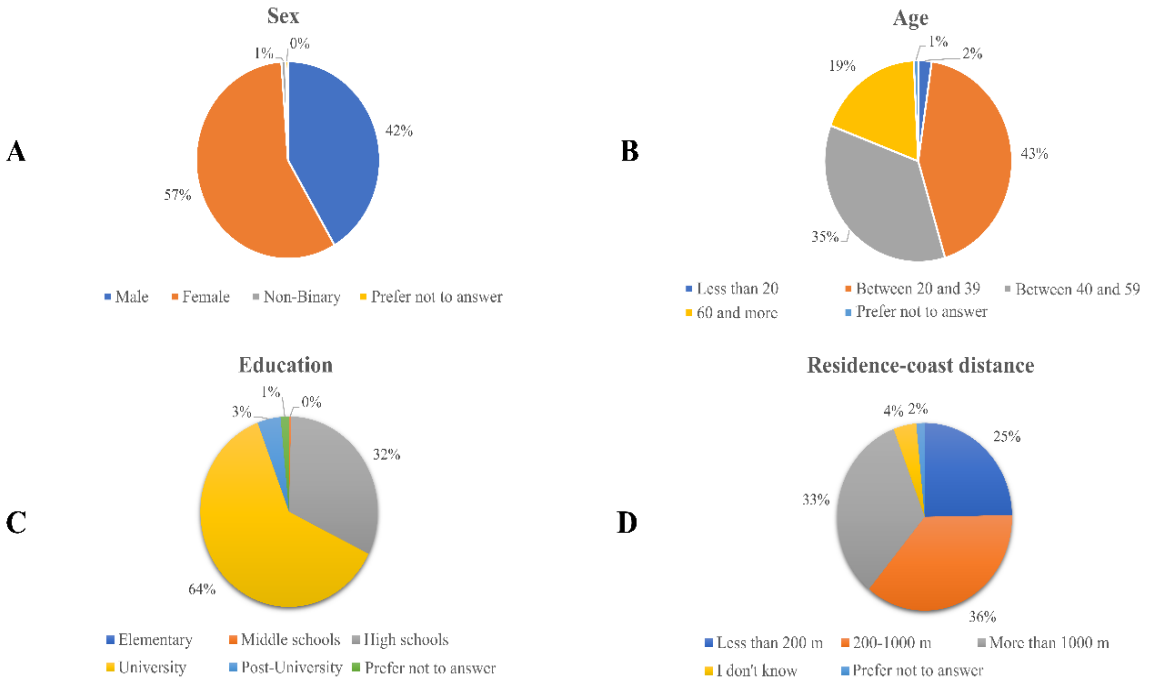

Figure 5. Biographical data of respondents to the online questionnaire.

As for the semi-structured interviews, a total of 15 were conducted, including four in Lazio and the remainder in Campania (Table 3). Most of the interviewees were males (10) and aged between 40 and 59 years (8). Regardless, we were able to reach a wide variety of stakeholders, including beach managers (3), fishermen (3), activists (2), authorities/politicians (2), hoteliers (2), researchers (2), and a media expert. While the questionnaire did not specifically assess occupational segmentation concerning risk perception, insightful findings emerged from qualitative interviews, which will be elaborated upon in subsequent dedicated sections. Without making definitive claims, a general observation suggests that individuals in distinct occupational realms exhibit varied perspectives. Activists and researchers, for instance, demonstrate a comprehensive understanding of potential impacts and perceive risks across short, medium, and long-term timelines. In contrast, beach and tourism workers predominantly view climate change through an economic lens, framing it as a potential financial risk. Fishermen, on the other hand, tend to focus more on environmental degradation and pollution rather than climate change in its entirety. These nuanced distinctions highlight the diverse lenses through which different occupational groups interpret and engage with the concept of risk.

In the following sections we report a summary of the key perspectives and problems identified by the surveyed people.

Table 3. Summary table of the interviewed actors.

ID	Sex (M/F), Age	*Profession*	Municipality	Date
1	F, 45	*Lawyer and activist*	Bacoli (NA)	08/04/2023
2	F, 37	*Media worker*	Pozzuoli (NA)	11/04/2023
3	F, 43	*Researcher*	Mondragone (CE)	14/04/2023
4	F, 70	*Former Department of Tourism, Campania Region*	Giugliano in Campania (CE)	18/04/2023
5	M, 53	*Hotelier*	Mondragone (CE)	18/04/2023
6	M, 48	*Hotelier*	Mondragone (CE)	18/04/2023
7	M, 83	*Opposition party, ex-unionist*	Mondragone (CE)	19/04/2023
8	F, 35	*Researcher*	San Felice al Circeo (LT)	26/04/2023
9	M, 43	*Editor-in-chief and activist*	Pozzuoli (NA)	04/05/2023
10	M, 67	*Fisherman*	Cellole (CE)	06/05/2023
11	M, 56	*Fisherman*	Cellole (CE)	06/05/2023
12	M, 49	*Fisherman*	Cellole (CE)	06/05/2023
13	M, 69	*Beach manager*	Minturno (LT)	06/05/2023
14	M, 57	*Beach manager*	Minturno (LT)	06/05/2023
15	M, 64	*Beach manager*	Minturno (LT)	06/05/2023

4.1. Did somebody say «climate change»?

In general, most respondents express concern about climate change (88.7%) and the impact it will have on their lifestyle (79.8%). Likewise, there is agreement in believing that these are direct consequences of human activities (86.0%). Much more in doubt is the possibility that they may be reversible (37.6% agree or completely agree, while 41.1% are neutral). On this last aspect, it is interesting to note that the hope in the possibility of counteracting the current climate trend, in percentage, increases with age: from 36% of the 20–39 bracket to 43% of the over-60s (Figure 6). The exception is only the under-20s, who are equally divided between agreement and disagreement, but it is worth mentioning that there are only 6 respondents.

Another aspect that seems positively related to the hope for climate change reversibility is the level of education. As the level of education increases, the percentage of people who do not consider climate change reversible also decreases (Figure 6). Indeed, emblematic is the case of respondents with an education level corresponding to middle school who, although few (only 3), agree in not taking a position. Finally, no real gender trend emerges, although it should be noted that women emerge among the most positive respondents about the future (41% versus 33% of men).

Beyond the reversibility of the climate crisis, 83.3% of respondents declare that, for effective action in terms of reducing the impacts of climate change, personal lifestyles will also need to be changed. In the open-ended responses, most (70.4%) state that it is necessary to adopt a more sustainable and responsible lifestyle, reducing waste in general, whether in terms of energy, food, water, or products. Specifically, it is considered important to: (i) limit the use of cars, preferring environmentally friendly means of transportation such as bicycles or public transportation; (ii) choose more sustainable foods and products, including reducing the consumption of meat and fish (especially if they come from intensive livestock farms), prefer zero-mile foods, and reduce food waste; (iii)

reduce the use of plastics, recycle them, and prefer more environmentally friendly materials; (iv) reduce energy consumption by using heating and electricity systems more efficiently; (v) switch to renewable energy sources such as solar energy; (vi) reduce the use of chemicals and non-biodegradable materials; and (vii) be active, responsible, and environmentally aware citizens.

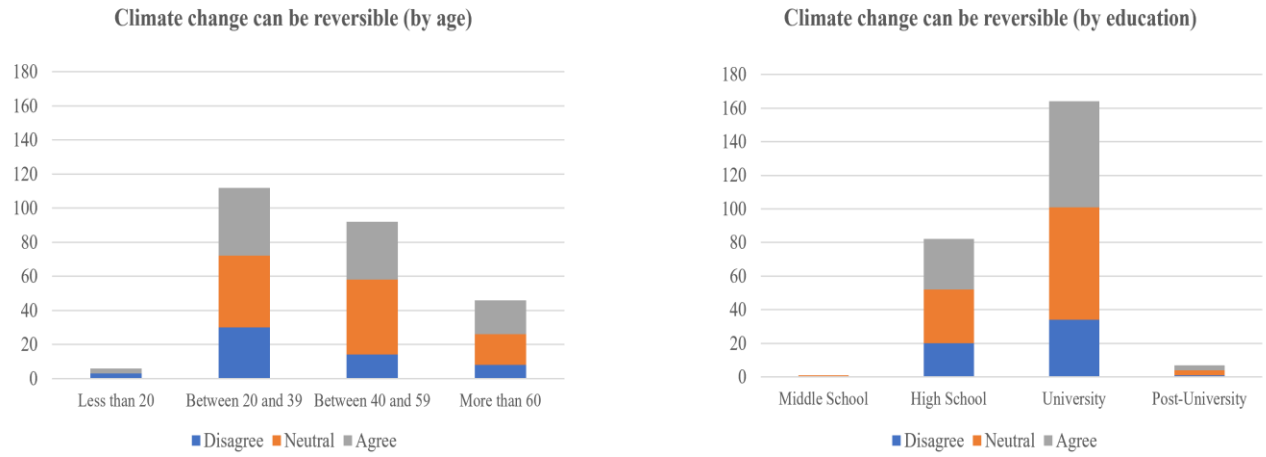

Figure 6. Bar charts comparing the responses to the question "Climate change can be reversible" by age group and education level.

At the local scale, the perception of climate change focuses on weather phenomena (with 37.8% of respondents expressing this preference), particularly referring to "changes in temperature", followed by "changes in precipitation patterns" and the appearance of "extreme weather conditions" (Figure 7). However, among the respondents, a notable degree of uncertainty is observed regarding the possibility that these phenomena are becoming more important than other risks in their Municipality. The second concern of the residents in the Gulf of Gaeta is pollution (17.7%), which includes the increase in "environmental pollution", both in the air and in the water, and the "deterioration of ecosystems". Furthermore, health (16.2%) is an aspect of great relevance, with particular attention to the current negative impact of climate change on human health. To a lesser extent, but still noteworthy, there is concern about the possible onset of "epidemics or pandemics". Surprisingly, economic factors (14.6%), such as "rising costs of living" and, to an even lesser extent, "economic decline", appear to be less related to climate change at the local level. Access to resources, particularly "drinking water" (13.4%), shows an even less pronounced association. It is noteworthy that, even though fewer respondents acknowledged the lesser-renowned impacts of climate change linked to health, economy, and access to resources, they indeed displayed the highest percentage of agreement regarding the "increasing significance of climate risks within their territory" (40.7% for "health", 38.5% for "economy", and 39.1% for "access to resources"). Conversely, individuals who only acknowledged the more common impacts, such as meteorological phenomena and pollution, appear more uncertain about the importance of climate risks in their community (40.9% for "meteorological phenomena" and 38.6% for "pollution" are neutral). This observation helps us to profile a compelling pattern: the greater the recognition and awareness among individuals of the multifaceted effects of climate change and its pervasiveness in society, the higher the concern about its escalating impacts.

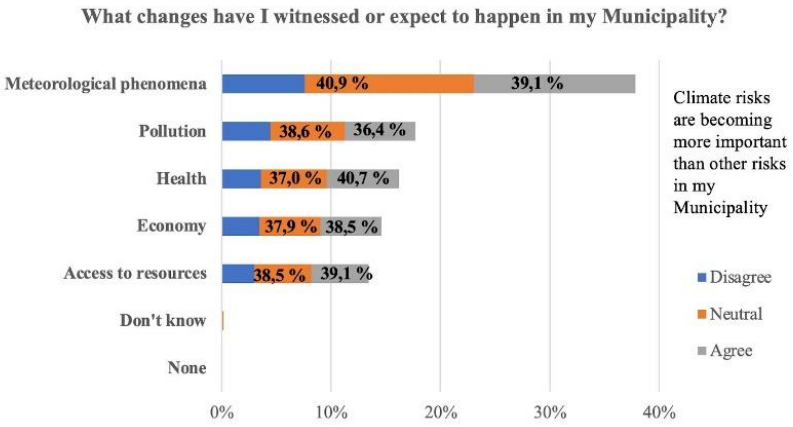

Figure 7. Bar chart illustrating the comparison between responses to two distinct questions of the questionnaire: the multiple-choice question "What changes have I witnessed or expect to happen in my Municipality?", juxtaposed with the Likert scale question "Climate risks are becoming more important than other risks in my Municipality (e.g., earthquakes, conflicts, pandemics, industrial accidents...)". The displayed percentage labels correspond to the most relevant Likert responses associated with each individual bar in the graph.

The survey also shows that most participants believe that the sea and coast of their Municipality are already affected by climate change, although this percentage does not reach particularly high levels (60.3%). It is important to note that a considerable segment of the sample chooses not to make a judgment on this issue (26.1%), while the remaining segment believes that these changes have no impact on the coastal area of their Municipality (13.6 %). However, as shown in Figure 8, both among the most skeptical and the least skeptical, the majority agree on the feeling that the coastline is increasingly undergoing a process of retreat and erosion (37.0%). Indeed, the entire Gulf of Gaeta area, with particular reference to Terracina and Sperlonga in Lazio and Castel Volturno and Sessa Aurunca in Campania, are among the hardest hit in the regions [53]. The percentage of respondents who share this concern is approximately the same as those who express disquiet about the intensification of extreme weather phenomena (Figure 7), but in the case of the coast the role of climate change is recognized more (68.4%).

The second phenomenon that seems to worry Gaeta Gulf residents, regardless of the ongoing climate crisis, is the process of beach degradation (21.7%) (Figure 8). Problems related to the presence of plastics and microplastics also emerge above all in the interviews: "There is more and more plastic. We don't know what we recover from the hooks." (respondent n. 10); "Sometimes I happen to fish and find the caps inside the fish, and it's a big problem." (12). There is also a visible level of pollution, reflecting poor management and control of purification systems and vessel discharges, especially in the summer period, that is not correlated with issues related to contextual weather-climate alteration: "The real problem is the cleanliness of the water. In my opinion, it is disgusting and there must be something because I get blisters if I bathe here." (14).

In addition to these perceptional elements, the remaining environmental processes that seem to be of interest to residents of the Gulf of Gaeta are sea level rise (17.3%), increased coastal flooding (16.9%), and, although only to a small extent, salinization of soils (5.9%) (Figure 8). Interestingly, among respondents who acknowledge the most well-known consequences of the environmental crisis

in their local area, there is a slightly lower level of agreement regarding the role of climate change. Specifically, 68.4% acknowledge its influence on "coastal erosion", 64.8% on "degradation", and 64.4% on "sea level rise", whereas in the case of "increased flooding" (72.9%) and "salinization" (71.1%), which are generally less-familiar phenomena associated with climate change, the agreement is relatively higher. Once again, a pattern emerges: individuals with greater knowledge and awareness of the potential consequences of climate change are more likely to recognize the presence of such phenomena at a local level and attribute their origin to climate change.

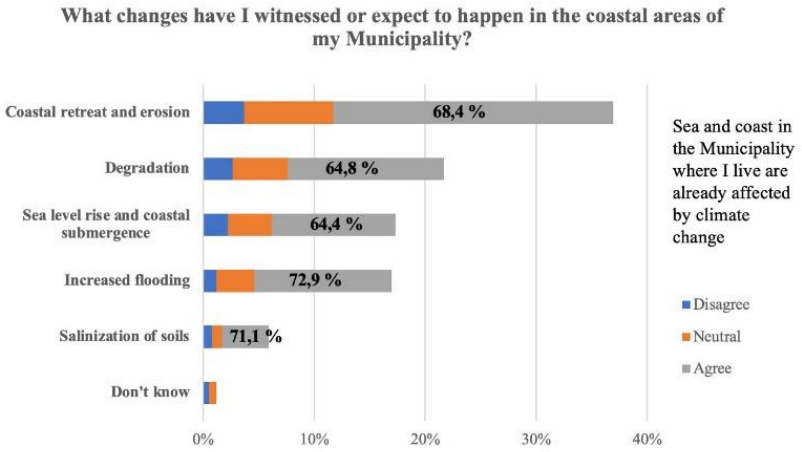

Figure 8. Bar chart illustrating the comparison between responses to two distinct questions of the questionnaire: the multiple-choice question "What changes have I witnessed or expect to occur in the coastal areas of my Municipality?", juxtaposed with the Likert scale question "Sea and coast in the Municipality where I live are already affected by climate change". The displayed percentage labels correspond to the most relevant Likert responses associated with each individual bar in the graph.

Finally, in the perception of survey participants, the "socioeconomic sectors" most likely to be impacted by climate change in local coastal areas include "coastal management" (14.5%) and "agriculture/livestock farming" (14.3%). In addition to direct impacts from the sea, it is recognized that seasonal and rainfall variations can have a significant impact on agricultural production. A sizeable proportion of respondents (13.2%) also mentioned "biodiversity and ecosystem conservation" as an area sensitive to climate change. This reflects a growing concern about habitat loss, ecosystem alteration, and species decline related to climate change. Furthermore, "water resource management" (10.6%) and "human health" (10.2%) emerge as areas of significant concern. In contrast, "tourism and recreation" (8.4%), "transportation and infrastructure" (5.3%), and "trade" (3.4%) seem not to receive as much attention, although these sectors may indeed be affected by climate change through previously mentioned processes such as coastline retreat, coastal erosion, and storm surges. For example, respondent no. 15 stated: "The beach is so in retreat that we managers have a big problem: the wind and storm surges erode the sand so much that we are left with little room for parasols and everything else". As a result, it emerges that one of the main obstacles is the still rather vague perception that citizens have regarding climate change. It is often seen as an external phenomenon without a full understanding of its implications or the various dimensions and scales at which it can manifest itself.

4.2. Private or public? That is the question

Having observed that climate change is a source of concern in coastal areas, albeit to a lesser extent and with less awareness of the possible consequences, it was considered that further analysis should focus on local actors who ought to be included in climate change response actions. Therefore, we investigated the perception of local governance.

In general, while the percentage of respondents fearing the climate crisis settled around 80% and above, doubts begin to arise when asked whether public institutions can respond effectively to the challenges posed by climate change (62.3% agree or completely agree). As found for the perception of the reversibility of the climate crisis, trust in the possibilities of public institutions also increases with age, up to a maximum of 82.6% for the over-60s (Figure 9). In contrast, there does not seem to be a relationship with either education level or gender. However, men emerge as the most confident in public institutions (65% vs. 61% of women).

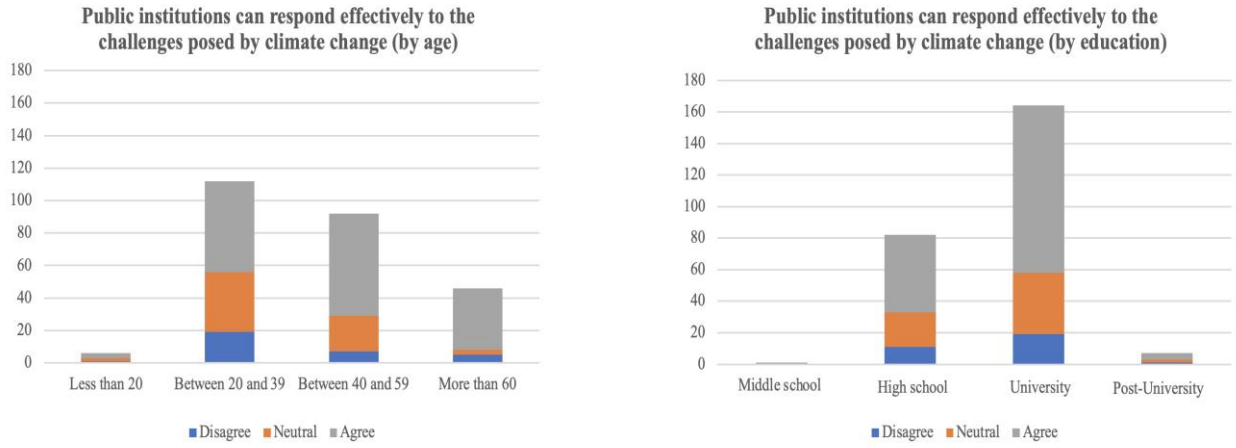

Figure 9. Bar charts comparing the responses to the question "Public institutions can respond effectively to the challenges posed by climate change" by age group and education level.

The fear that public institutions, from municipal to state level, may not be able to provide a comprehensive and effective response to climate change in coastal areas seems to vanish when respondents are asked which stakeholders should be involved. As many as 42.1% of respondents, regardless of their perception of climate change, believe that public institutions should play a "key role". In particular, it is suggested that the region and the state should play the dominant role and not the municipalities or, to a lesser extent, associations of municipalities. In sharp contrast, only 6.6% of respondents strongly hope for greater involvement of the private sector, including corporations and industries. Second, input from environmental and civil protection agencies (26.0%), which seem to enjoy a higher level of trust than experts and researchers (15.6%), is considered desirable, especially among those who believe that climate risks are growing within their Municipality. Finally, albeit to a lesser extent (9.3%), people recognize the importance of the work of "nongovernmental organizations" and "voluntary associations" play within their Municipality.

A deeper analysis reveals another insightful detail: participants residing in Campania tend to have higher expectations of intervention by public institutions (43.1% in Campania, 41.6% in Lazio) and government environmental and civil protection agencies (26.2% in Campania, 25.5% in Lazio) (Figure

10). This attitude could be attributed to the specific situation in the Campania Region, where 68.1% of the sandy coast is managed by concessions, many of which are private, for bathing establishments, campgrounds, sports clubs, and tourist complexes [53]. While the statistical disparities may not seem significant, our ability to interpret these differences with a deeper understanding was enabled by conducting contextual analysis, examining responses to open-ended questions in the questionnaire, and engaging in interviews with privileged actors.

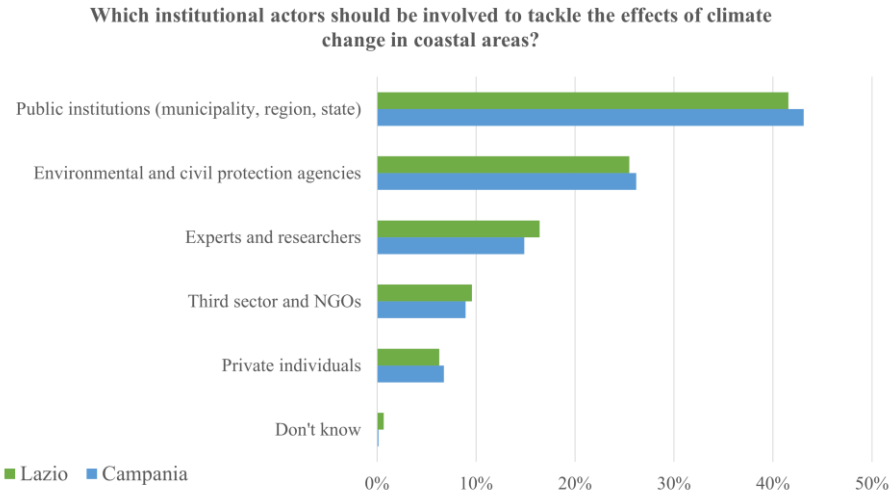

Figure 10. Regional distribution of the responses to the question "What institutional actors should be involved to tackle the effects of climate change in coastal areas?".

The above considerations are also confirmed in some comments that emerged from the interviews. In the Campania case it is reported that: "At the administrative level, you see fragmented actions and personalistic and micro-interests prevail" (1); "I see a lot of privatizations. Thus, where it is private it is well kept, while the public beach is very dirty, and the public authority is often linked to criminal activities" (2); "Coastal management is completely entrusted to private individuals" (4). The consequences of this private management, although in the short-to-medium term they have maintenance and "decency" effects, cause irreparable damage to local biotypes. For instance, in Cellole the sandy dunes are "flattened" to allow the managers of the establishments to have more space available because of the tourist season (Figure 11). This issue, as is evident, has important implications, since the dune belt not only represents an environment of great naturalistic and ecological interest, but also delimits and protects the wetlands of great ecological importance behind it. Moreover, this specific criticality to which the shoreline is exposed stands as a striking example of the conflict increasingly inherent in the coastal landscape between the production of economic goods and the production of "environmental" goods [54] (p. 20).

By contrast, in Lazio, the percentage of privately managed areas decreases to 40.8%, and the coastal strip is characterized by less urbanization. This is partly due to the Regional Plan for the Use of the Beaches, which reiterates that each Municipality must reserve it for "public use" (i.e., free beach or free beach with services) a share equal to at least 50% of the sandy shore under its jurisdiction, without prejudice to the right of each Municipality to set a higher percentage. Finally, in Lazio, there is a greater preference for the involvement of experts and researchers, while in Campania there is a greater inclination for private involvement.

Figure 11. Foredune in the public beach (left), disappearing in the part under private management (right) in Cellole (CE).

These regional differences suggest that specific local contexts influence perspectives and preferences regarding actors involved in coastal areas in climate change management. The emergent citizen demand for action by institutions, especially supra-municipal institutions, could be a consequence of the historical conflicts related to land use in these coastal areas [26]. Such historical and cultural contexts should be carefully considered when planning climate change response interventions.

4.3. Collective actions to protect a common good

Once we examined who should be involved in coastal hazard mitigation initiatives, we focused on residents' perceptions of activities already implemented by local institutions, including their awareness and knowledge of the responsible parties. Surprisingly, more than 90% of participants (236) said they were not aware of any initiatives introduced by local institutions. The few who responded in the affirmative mainly referred to initiatives such as the creation of artificial reefs and orthogonal groins to protect the coast (2 in Lazio and 1 in Campania, Figure 12), as well as interventions led by volunteer and activist associations (1 in Lazio and 1 in Campania), and beach cleaning actions such as banning the throwing of cigarettes and picking litter (1 in Lazio and 1 in Campania). Other initiatives reported in the Lazio Region are beach nourishment at the beginning of the tourist season (2) and the creation of marine protected areas in the Circeo National Park (1). In the Campania Region, on the other hand, reference is made to the European Regional Development Fund 2014/2020 (1) and the construction of dunes to reduce the loss of sand (1). These kinds of interventions were mentioned, in both cases, by residents of the Municipality of Mondragone, where the Urban Dune Park was built to restore the natural ecosystem of coastal dunes.

Figure 12. Panels that prevent the dispersion of sand, in Mondragone (CE).

Although survey participants manifest a substantial lack of information regarding initiatives launched by local institutions or other agencies, they do not seem to perceive a pressing need for greater involvement in planning processes. In fact, when asked to express "what they would like to be done for the future of their Municipality's coastline", only 136 participants (corresponding to 53% of the sample) indicated such a preference. Instead, the priority seems to be the implementation of projects aimed at coastal renaturalization, including "specific projects to protect marine and coastal biodiversity" as well as the "establishment of protected areas". This preference is particularly pronounced in Campania, where 47.5% of participants expressed this opinion, compared to 43.6% in Lazio, as shown in Figure 13. However, this willingness seems to conflict with the idea, prevalent in Campania, of allowing the installation of additional physical barriers for flood protection (e.g., groins or reefs) (17.4% in Campania, 16.8% in Lazio) and the increase in tourist capacity and accommodation and logistics infrastructures (such as ports, roads, and railways) (16.8% in Campania, 14.2% in Lazio). However, these interventions could contribute to greater anthropic development of the coastal strip, generating potential conflicts between the goals of preserving the nature of the coast and of promoting greater human activity. On the contrary, over the latter possibility, the respondents from Lazio seem to place the need to mitigate anthropic pressure through the reduction of tourist influx and related port and linear infrastructures (14.7% in Lazio, 10.7% in Campania).

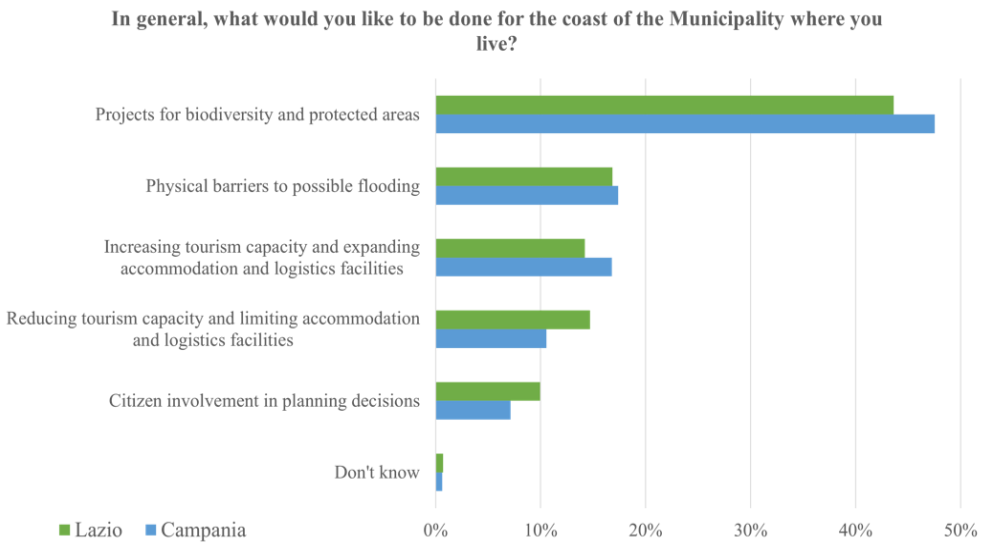

Figure 13. Regional distribution of the responses to the question "In general, what would you like to be done for the coast of the Municipality where you live?".

The dichotomy between the demand for ecosystem solutions to coastal problems and the need to maintain, if not increase, the influx of tourism to generate revenue emerges as a substantial issue in these territories. Planning for governance that is an expression of the variety of interests can no longer follow a "top-down" approach, but requires the adoption of "bottom-up" approaches that incorporate all scales of analysis into the debate [55]. This implies the active involvement of citizens to rebuild relations with local institutions and restore the trust and the motivation necessary to jointly address the challenges of the climate crisis.

Some proposals were advanced in the interviews, such as: "What could be done is widespread and institutionalized education in schools and, above all, meetings with local communities, stakeholders, and beach managers to explain the problem" (9). Also, in the "comments" of the online form emerged the urgency of targeted actions, but also of a general awareness of the issues, including—though not exclusively—in reference to climate change: "It is necessary to make all citizens aware of the risks and possible activities to safeguard our territories"; "If possible, this problem should be addressed concretely in all schools, from primary to secondary: few intellectual concepts, but practical activities that should be carried out directly by the students, of course under the guidance of competent people who can pass their knowledge with enthusiasm and care"; "I see that in my Municipality there are many land management problems (in general) […] I think that the influence of the climate has a significant impact. Just like the waste discharges from all the restaurant activities, which are often spilled into the sea, polluting, changing the ecosystem, and impacting the climate."

5. Conclusions

This research, which follows studies on the perception of risk related to the impacts of climate change, sought to provide an overview related to the situation of the coastal urbanized area of the Gulf of Gaeta (central Western Italy). The results of the conducted survey open up new considerations related to the components of risk perception and contribute to the understanding of the dynamics that amplify the vulnerability of the territory and the communities it hosts.

In particular, individual perception appears to be influenced by both individual socio-environmental characteristics related to the awareness of the ability to affect processes of change and the degree of trust in institutions. Additionally, the type of governance prevailing in a given area plays a significant role. The case study showed that in location where the management of the coastal resources is essentially entrusted to private individuals, the awareness of risk seems to be less prominent. Conversely, in contexts where the "public" mold of land governance prevails, citizens seem to be more aware of the articulation and complexity of environmental risks. Perception thus seems to vary according to the type of management in place. This finding contributes to the existing literature on the subject and underscores the importance of advocating for forms of partnership between different stakeholders and public bodies, emphasizing coordination as a prerequisite for integrated management, as indicated by international and national guidelines such as the Integrated Coastal Zone Management protocol or the National Guidelines on Coastal Erosion.

In this sense, it is highlighted how effective coastal risk management should require collaboration between public and private entities in sharing resources, expertise, and responsibilities. However, balancing public and private interests in coastal risk management appears to be a complex and dynamic process that requires effective communication. It is recommended, on the one hand, to create incentives for private entities to invest in risk reduction measures, such as, for example, tax incentives or subsidies for building resilient infrastructure. On the other hand, public policies and strategies should become more flexible and adaptable to take into account the changing environmental conditions and the evolving perceptions of risk, in collaboration with private entities. This analysis helped to highlight the multiple conflicts and challenges related to the global climate crisis from a local perspective. It shed light on how these transcalar issues are perceived by communities, emphasizing the layered areas of risk to which individual are exposed, thereby exacerbating their social and environmental vulnerability in multifaceted ways [56–58].

Specifically, several critical issues emerge, which can be correlated with building speculation, tourism, coastal defense works, and other activities, whether illicit or otherwise, that are extremely invasive (e.g., illegal dumping or silting up of streams) and profoundly affect the coastal riskscape and the local landscape. Conversely, at a more general level, there is a pervasive distrust of institutions and public bodies, a lack of coordination among the actors involved, and the overlapping of initiatives and functional entities gravitating to the area. These factors tend to exacerbate the consequences associated with governing a "hyper-territorialized" territory [59]. The costs incurred by the community due to this lack of organicity, considering both material and non-material damage, could potentially escalate as the consequences associated with meteoclimatic alterations increase.

Moreover, the interviews with privileged actors suggest that the active involvement of the local community (to foster responsibility and resilience among citizens), as well as the engagement of all stakeholders, are crucial measures to effectively counter these impacts and reduce the vulnerability faced by the population. There is still a long way to go, although the participatory approach is now considered to be at the heart of all policy planning, precisely because decisions affecting the environment and society cannot disregard the transcalar dimension that connects local and global issues. In this regard, Principle 11 of the Rio Declaration on Environment and Development states that "environmental issues must be managed with the participation of all concerned citizens, at the relevant level. [...] Every individual must have adequate access to information about the environment held by public authorities, including information about hazardous materials and activities in their communities, and the opportunity to participate in decision-making" [60]. Hence, it is crucial to adopt timely and

planned adaptation strategies to enhance governance effectiveness and coordinate policies. This involves promoting transparency, communication, and accessibility of data, possibly using GIS-based Territorial Information Systems already available at the regional scale. Clear, transparent, and timely information on potential risks and preparedness measures can help shape public perceptions and encourage proactive responses.

In conclusion, these harmonized approaches could start by considering the Gulf as a unicum, embracing its physical-morphological unity while seeking to overcome administrative and institutional barriers [61]. The implementation of unified strategies and activities consistent with the characteristics of the area as well as with current and future predictions of climate change impacts is essential. Such a cohesive planning approach, in this context as elsewhere, holds the potential to streamline the administrative framework by generating a functional zoning that would address the dysfunctions given by the overlapping of territorial entities. This approach would optimally allocate areas of competence and foster a more balanced consultation among the various entities involved. This integrated and inclusive vision could, thus, help to ensure coherent action in the face of present and future climate challenges, identifying more efficient spatial areas, and contributing not only to the full awareness of populations but also to a policy aimed at reducing their risk exposure [62].

Use of AI tools declaration

The authors declare they have used the aid of Artificial Intelligence (AI) tools for a preliminary check on the English rendition of this article.

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Eleonora Gioia: Conceptualization, Methodology, Data Analysis, Results and discussions, Writing—original draft; Writing—review & editing (1, 4). Eleonora Guadagno: Conceptualization, Field research and Data collection, Results and discussions, Conclusions, Writing—original draft (2, 3, 5).

Conflict of interest

The authors declare no conflicts of interest in this paper.

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Supplementary

Annex 1. Summary table of questions in the online survey.

Section	Question	Type	Answer(s)
Demographic data	Sex	Single choice	Male; Female; Non-binary; Prefer not to say
	Age	Single choice	Less than 20; between 20 and 39; Between 40 and 59; More than 60; Prefer not to say
	Municipality of residence	Single choice	San Felice Circeo; Terracina; Fondi; Sperlonga; Itri; Gaeta; Formia; Minturno; Sessa Aurunca; Cellole; Mondragone; Castel Volturno; Giugliano in Campania; Pozzuoli; Bacoli; Prefer not to say
	Residence-coast distance	Single choice	Less than 200 m; 200-1000 m; More than1000 m; I don't know; Prefer not to say
	Education	Single choice	Elementary; Middle; High school; University; Prefer not to say; Other (specify)
Climate change perception	I am concerned about the current climate crisis	Likert scale	Strongly disagree (1); Disagree; Neutral; Agree; Strongly agree (5)
	Climate change will impact my lifestyle	Likert scale	Strongly disagree (1); Disagree; Neutral; Agree; Strongly agree (5)
	The speed of current climate change is a direct consequence of	Likert scale	Strongly disagree (1); Disagree; Neutral; Agree; Strongly agree (5)

	human activities		
	Climate change can be reversible	Likert scale	Strongly disagree (1); Disagree; Neutral; Agree; Strongly agree (5)
	Public institutions can respond effectively to the challenges posed by climate change	Likert scale	Strongly disagree (1); Disagree; Neutral; Agree; Strongly agree (5)
	To effectively tackle climate change, do I have to change or give up something about my lifestyle?	Single choice	No; Yes
	If yes, what?	Open	
Climate change perception in the Municipality	What changes have I witnessed or expect to happen in my Municipality?	Multiple choice	Changes in temperature, Changes in quality/access to drinking water, Drought, Extreme weather conditions, Changes in rainfall patterns, Increased pollution in water and air, Degradation of ecosystems, Economic decline, Increased cost of living, Negative impact on human health, Epidemics/pandemics, None, Don't know
	What changes have I witnessed or expect to happen in my Municipality? (Other)	Open	
	Climate risks are becoming more important than other risks in my Municipality (e.g., earthquakes, conflicts, pandemics, industrial accidents...)	Likert scale	Strongly disagree (1); Disagree; Neutral; Agree; Strongly agree (5)
	The sea and coast in the Municipality where I live are already affected by climate change	Likert scale	Strongly disagree (1); Disagree; Neutral; Agree; Strongly agree (5)
	Which of the following sectors is most affected by the effects of climate change in the coastal areas of the Municipality where I live?	Multiple choice	Agriculture / Livestock, Biodiversity / Ecosystem conservation, Coastal management, Emergency and rescue services (e.g., civil defense), Electricity production and distribution, Human health, Land use and management, Tourism and recreation, Transportation and infrastructure, Water resource management, Industry, Trade
	What changes have I witnessed or expect to happen in the coastal areas of my Municipality?	Multiple choice	Beach degradation, Erosion, Sea level rise and coastal submergence, Beach retreat, Increased flooding (storm surges, cyclones, etc...), Soil salinization, Don't know
	What changes have I witnessed or expect to happen in the coastal areas of my Municipality? (Other)	Open	
Local governance perception	Which institutional actors should be involved to tackle the effects of climate change in coastal areas?	Multiple choice	Municipality, Associations of municipalities, Region, State, Civil protection, International organizations, Government agencies, Environmental agencies, Society and industry,

			University, Non-governmental organizations, Experts/Technicians, Voluntary associations, Don't know
	Which institutional actors should be involved to tackle the effects of climate change in coastal areas? (Other)	Open	
	Are you aware of activities aimed at reducing coastal risk implemented by local institutions?	Single choice	No; Yes
	If yes, which ones?	Open	
	In general, what would you like to be done for the coast of the Municipality where you live?	Multiple choice	Specific projects to protect marine and coastal biodiversity, Establishment of protected areas (e.g., parks/reserves), Increased physical barriers for possible flooding, Increased tourist accommodations, Reduced tourist inflow, Increased port infrastructure, Increased linear infrastructure (roads/rails), Reduced port infrastructure, Reduced linear infrastructure (roads/rails), Citizen involvement in planning decisions, Don't know
	In general, what would you like to be done for the coast of the Municipality where you live? (Other)	Open	
Other comments	Do you want to add other comments regarding the topic of the survey?	Open	