Anthropocene Coasts

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Prioritizing environmental policies in Greek coastal municipalities

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Abstract

The aim of the present contribution has been to present a methodological framework to gauge/assess the perceptions and identify the policy priorities of local-decision-makers for the management of the coastal zone under a changing climate, on the basis of structured 'interviews' of the local decision makers. The framework was applied in two different coastal areas in Greece: a) Elefsina, an urban-industrial area west of Athens with a long industrial history (and the 2023 European Capital of Culture); and b) the Aegean island of Santorini/Thera, a major international tourist destination due to the rare aesthetics of its volcanic landscape. The framework implementation showed that a) policy prioritization is characterized by an (understandably) overarching objective to address immediate environmental and socio-economic challenges in short time tables due also to constraints in appropriate human and financial resources and the reliance on higher governance (regional/national) levels; b) policy axis and action prioritizations are controlled by the local environmental setting and development model; c) interestingly for coastal municipalities policy actions associated with the study/protection of coastal ecosystems ranked very low albeit for different stated reasons; and d) climate change impacts and adaptation have not been prioritized highly in both coastal municipalities, in contrast to the large impacts and needs for adaptation projected for these areas and the evolving policy and legislation frameworks. It appears that higher efforts should be made in terms of the assessment of climate change impacts, and the dissemination of the assessment results and the relevance of the evolving policy and legislation regimes to the local policy makers.

Keywords Coastal environmental policies, Climate change impacts, Coastal management decision, Prioritization, Coastal erosion

1 Introduction

The concept of sustainable development is based on three pillars, namely economic growth, social progress and environmental quality (UN 2013). It follows that integrated approaches are required in the assessment and management of the sustainability of the environmental systems, which presuppose cooperation and coordination of actions by the relevant actors, including of different levels of governance. The new EU Strategy on Adaptation to Climate Change prescribes the design and implementation of adaptation policies and plans at all levels of governance, having three cross-cutting priorities (EC 2021a): integration of climate change adaptation into economic policy, adaptation actions by local policy makers, stakeholders and communities and promotion of nature-based solutions.

In coastal environments, an overarching management vision is to aim at healthy and climate-resilient marine/coastal ecosystems that provide benefits for both the present and the future generations (UNEP 2019). This vision can be realized by integrated coastal zone management (ICZM) frameworks. A most important determinant of the effectiveness of these frameworks is governance, which should be both coherent and dynamic in the

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rapidly changing (demographically, environmentally and socio-economically) coastal zones. However, limited attention has been paid to policy settings (Beeharry et al. 2014), with institutional perceptions and associated policies being often the weak links in ICZM planning and practices (Gallagher 2010; Elrick-Barr and Smith 2021).

The assessment/management of the coastal zones' risks under the changing environmental conditions are defining ICZM challenges and particularly relevant at local levels where local policy/decision makers determine the success of integrated management policies. Local policy makers (authorities) manage the local environmental, economic and social infrastructure, set up local environmental policies and regulation and oversee the planning process, and assist in the implementation of the international, European and national environmental policies and legislation (Velegrakis et al. 2021; Velegrakis et al. 2022). As the level of governance closest to the coastal communities, local decision makers play a vital role in responding to local environmental emergencies and the promotion of local sustainable development policies (UN 1993).

Management of the coastal zone at the local level depends on both local needs and perceptions. Coastal areas with different environmental characteristics, demographics and development models usually have different requirements and policy priorities; these are also controlled by the information available and the policy-maker perceptions. Policy prioritization by local decision makers requires a structured process through which priorities could be identified in terms of wider policy objectives and legislation. This prioritization can affect the distribution of the available human and financial resources for the implementation of efficient management responses (Andreadis et al. 2021). It is noteworthy, however, that despite the 'policy space' afforded to local decision makers with regard to coastal planning (Balla and Giannakourou 2020), existing ICZM policies and measures do not always take into sufficient account local perceptions and environmental and socio-economic particularities. It is necessary, therefore, to gain insights into the perceptions and the associated policy prioritization by local decision makers.

The objective of the present contribution is to present a methodological framework to gauge/assess through structured interviews the perceptions and identify the policy priorities of local decision makers for the management of the coastal zone under a changing climate. The findings are then discussed focusing particularly on the prioritization of policy actions associated with the assessment/management of climate change impacts. The framework was applied in two different coastal local administrative areas in Greece (Fig. 1): a) Elefsina Municipality, an industrial community close to Athens with a long cultural history (the 2023 European Capital of Culture); and b) the island municipality of Thera/Santorini, a major international tourist destination due to the rare aesthetics of its caldera created by a large volcanic eruption some 3,600 years ago that had very significant implications for the development of Eastern Mediterranean civilizations in the Late Bronze Age (Cole-Dai et al. 2021).

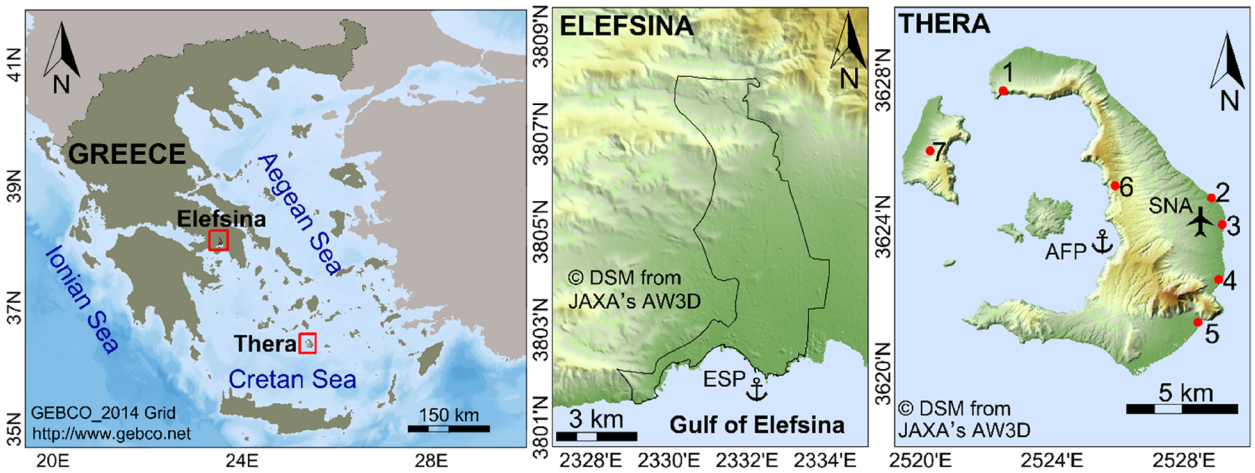

Fig. 1 Location map of the study areas (Elefsina and Thera/Santorini). In the Elefsina panel, the black line delineates the boundaries of the Municipality of Elefsina. Key: ESP, Elefsina seaport; SNA, Santorini National Airport; AFP, Athinios (Thera) Ferry Port; 1, Oia; 2, Monolithos; 3, Ag. Paraskevi; 4, Kamari; 5, Perissa; 6, Thera; 7, Therasia

2 Methods

The proposed framework involves three phases (Fig. 2). First, potential challenges of the local coastal zone are identified on the basis of the collation, evaluation and expert analysis of the available information on the environmental, social/demographic and economic conditions/trends and existing environmental protection policies and plans (Phase I). Secondly, the findings are summarized, coded, and presented to the appropriate decision makers in the study areas' local authorities i.e., the Municipalities of Elefsina and Thera (Phase II). Following the presentation of this information, the policy makers are asked for their perceptions and policy priorities (Phase III).

The framework differs from previous relevant work (e.g., O' Riordan 2014; Buono et al. 2015; Elrick-Barr and Smith 2021), as it targets directly local decision makers to gauge their views and prioritizations following presentations of wide ranged collated information. It allows for a combination of the environmental and socio-economic information and the political thinking of the local authorities at a given time to inform policy prioritization. It should be mentioned, that although the Greek national authorities hold the hard core of competencies related to the management of the coastal zone, Local Administrative Units – LAU (EC 2022), such as Elefsina and Thera, have also competencies for defining and cross-cutting coastal development issues, such as local spatial planning, issuance of building permits, provision of advice/consent on operational licensing, administrative control and enforcement of local environmental measures (Giannakourou and Balla 2015; Velegrakis et al. 2021). These competencies have been considered in the design of the policy actions questionnaire (Section 2.2).

2.1 Identification and codification of challenges

The available information on the coastal natural and human environments of the study areas was collated, including that associated with: a) the land morphology/use, the meteorological/oceanographic conditions and the air and water quality; b) the socio-economic development (demographics and development indicators in e.g. health, education); c) potential coastal hazards, such as hydro-meteorological (floods, sea level rise), geological and other health/safety hazards (e.g. wildfires and pandemics, Perillo et al. (2021)); and d) the availability of financial and human resources and the coordination/cooperation structures. This information was then ordered/coded into data fields (Table 1), evaluated and assessed to identify potential challenges.

In terms of the evaluation of the information presented to decision makers, codes were assigned to declare the origin of the information and its spatio-temporal scope in each study area. Regarding the source reliability, (open source) information from state, supra-national (EU) or international organizations was assigned a '*1*', information from relevant scientific research and/or private entities a '*2*', whereas when data reliability was explicitly stated (by the source) as low, a '*3*.' Spatial scope got an '*a*,' if the information covered the whole municipality, a '*b*' for information on some locations only, and a '*c*' when data represent the situation in a wider (administrative)

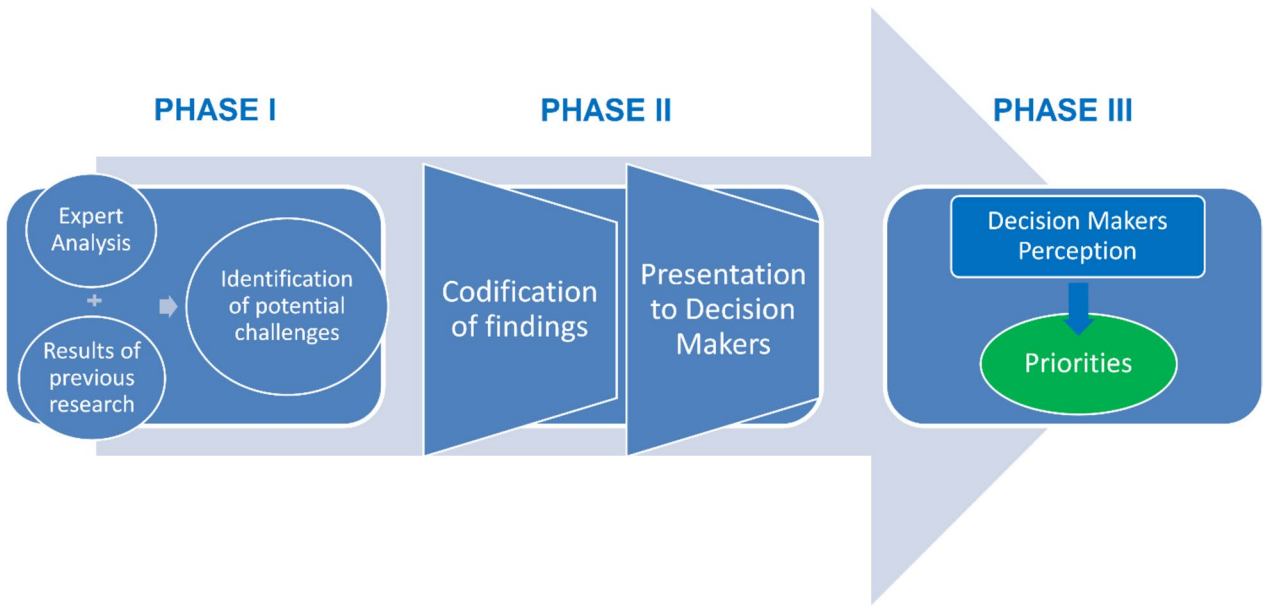

Fig. 2 Coastal policy prioritization framework

Table 1 Data fields (number) considered for the coastal natural and human environments

Information	Data fields
Coastal Environment (CE)	
Sea	9
Land use	2
Atmospheric data	6
Climate data	2
Socio-economic development (S-ED)	
Human development indicators	2
Demography	10
Economy	18
Education	7
Health, Pollution	6
Pollution	6
Hazards- risks (*H-SR*)	
Geological hazards- risks (e.g., earthquakes, landslides, tsunamis)	3
Climatic risk (e.g., heatwaves, extreme winds)	3
Flood risk (e.g., fluvial, pluvial)	1
Extreme sea level	4
Accidents/pandemics	2
Coordination and cooperation structures (C-C)	
Investment	3
Added value of economic activities	3
Availability of scientific staff	1
Program statements of the municipal authority	1

area and should be down-scaled before using. Information referring to the recent time period (2016 - 2020) has been assigned an '*i*', that for the 2011 - 2015 period a '*ii*', and older information (2010 or older) a '*iii*'.

Finally, the reviewed information was presented to the decision makers of the Elefsina and Thera Municipalities to inform their policy prioritization.

2.2 Policy makers perceptions and policy priorities

Following the presentation of the information to the decision makers in each municipality, these were asked to determine the importance they attach to four coastal policy axes in their strategic planning: the Coastal Environment (CE) axis aiming at addressing local coastal environmental problems; the Socio-economic Development (S-ED) axis, i.e., the planning and implementation of policies for local development; addressing risks to human safety/health (H-SR axis) related to measures addressing potential safety and health risks with an urgent need of mitigation/management (e.g., fires, fluvial, pluvial and marine floods, earthquake/tsunamis, health epidemics/pandemics); and the coordination-cooperation (C-C) axis, i.e., policies for the development and effective operation of governance structures, as well as stakeholder cooperation with a view to address sustainability challenges. Following the axis selection, decision makers were then asked to choose the policy actions they considered as most important for their municipalities between 20 categories of policy actions associated with the above policy axes (Table 2).

The prioritization by the policy maker selections involved: a) comparison of the four policy axes in pairs, which yielded a weight to be assigned to each axis; b) pairwise comparison of the 20 categories of coastal policy actions and grading/valuation on the basis of the selection order; and c) determining the overall prioritization of each category of policy actions, on the basis of their selected order, normalized on the basis of the weight of the policy axis to which it is directly related.

3 Results: framework implementation

3.1 Identification and codification of challenges

3.1.1 Challenges in elefsina municipality

The collated information was evaluated for reliability according to the criteria detailed in Section 2.1 (Table 3), with the most important findings from this exercise highlighted below. First, the S-ED is the policy axis with the most available information, particularly in terms of (open access) information from public organizations – '1' code); at the same time, a large part of this information is associated with aggregated information from a wider area (code 'ç'). Secondly, local information on the CE challenges is rather sparse. Thirdly, there is some recent information on coastal hazards/risks, but sparse earlier information to assess trends. Finally, it appears that there is little information available on C-C challenges.

The main characteristics and challenges identified from the available/reliable information for the different policy axes are summarized below. The Municipality of Elefsina (Fig. 1) is located about 20 km to the west of Athens, covers an area of 36.6 Km^2, is highly industrialized and has a population of 29,900 (a density of 817/km^2, national average 83.3/km^2). In 2018, the land use in the municipality was dominated by industrial/commercial zones, discontinuous urban fabric, road/railway networks and seaport facilities. There are also hardwood vegetation, transitional shrubs and woods in the northern/western areas of the municipality, as well as mineral extraction sites, whereas in its southwestern part there are also olive groves (YPEN 2018). Minimal land use changes were recorded since 2012, mostly related to the conversion of arable land into urban uses (Copernicus 2021).

Due to the intensive industrial activity since the beginning of the 20th century, Elefsina's coastal environment has been degraded; during the recent decades, however, implementation of environmental policies, development

Table 2 Coastal policy axes and directly related actions

Axis	Acronym	Policy Action	Policy Action
Coastal environment	**FLO**	FLORA	Study/monitoring of (wild) flora
	FAU	FAUNA	Study/monitoring of (wild) fauna
	BIO	BIODIVERSITY	Biodiversity assessment and protection measures
	CCH	CLIMATE CHANGE	Improved knowledge/assessment of climate change impacts; adaptation planning
	W	WATER	Study of water resources and systems; measures of rehabilitation/preservation
Socio-economic development	**AHR**	ACCESS TO HEALTH RECREATION	Improving access to the coastal recreation/leisure; improvement of health/social care services
	POL	POLLUTION	Study/monitoring of pollution; protection measures
	ENE	ENERGY	Activities related to energy production
	SFA	SHIPPING FISHING AQUACULTURE	Local policies for shipping, fisheries and aquaculture
	DEV	DEVELOPMENT	Demographic/educational issues; promotion of new economic activities
Health and safety risks	**FL**	FLOODS	Assessment of flood events; flood protection works
	ESL	EXTREME SEA LEVEL	Assessment of extreme sea level; adaptation measures
	STR	STORMS	Assessment of storm wind events; adaptation measures
	EROS	EROSION	Assessment of coastal erosion; protection measures
	OH	OTHER HAZARDS	Assessment of other hazards/risks (earthquakes, tsunamis, fires, heatwaves, pandemics); protection measures
Coordination and cooperation	**CCC**	COOPERATION COORDINATION COMMUNICATION	Improvement/upgrading of administration structures; coordination/development of collaborations; information services
	ENF	REGULATION AND ENFORCEMENT	Preparation of legislative/regulatory work; distribution of financial and human resources
	SPE	SPECIES	Appropriate measures for protection of endangered, threatened species; invasive species assessments
	NRE	NOURISHMENT RESTORATION RESILIENCE	Robust ecosystem restoration and resilience projects; beach replenishment
	RSR	RESEARCH	Further research on all above challenges

of modern infrastructure and the reduction in polluting industrial activities (due also to the challenging/changing economic conditions) have improved (to a degree) the environmental quality. In 2020, air quality in the Elefsina town center has been classified as 'good' (14.3%), 'fair' (69.5%), 'moderate' (9.9 %) and 'poor' (7.3%) of the time, according to the European Air Quality Index (EEA 2020). In comparison, the ecological status of the adjoining Gulf of Elefsina (Fig. 1) has been characterized as needing considerable improvement by the Greek Secretariat for Water of the Ministry of Environment, Energy and Climate Change (YPEKA 2013). Benthic hypoxic/anoxic conditions have been recorded due to the significant nitrogen/phosphorus loading facilitating eutrophication (SSW 2020). The particulate Cd concentrations recorded in 2013 - 2015 were at unacceptable high levels, showing similar values to those in 1977 (i.e., before the implementation of mitigating measures); in comparison, Zn and Mn concentrations were found to be within the limits of the Greek and European legislation and other metal concentrations also showed declining trends (Makeroufa 2016). It appears that there are very significant challenges relating to the ecology/pollution of the coastal marine environment, requiring a policy focus.

Population life expectancy at birth in 2018 was 81.3 years (national average 82.1 years), and the Human Development Index (HDI) and the Gender Development Index (GDI) were 0.895 and 0.968, respectively (Global Data Lab 2020; UNDP 2022). Economic data (2017) show that the largest share in the municipality's economic activities (total Gross Value Added) was associated with: mines, quarries, industry, energy and water supply, wastewater treatment and waste management/remediation (29.1%); and wholesale/retail trade, transportation maintenance/repair, storage, and catering services (28.7%). Most economic activities showed a decrease in total Gross Value Added between 2010 and 2017 (ELSTAT 2020). These data suggest that there is a need for 're-invention' of the local development model requiring targeted policy actions.

Table 3 Classification of reliability of available data for the municipality of Elefsina. For details of the codification of data reliability, see Section 2.1

Data Fields	Data Reliability										
	1ai	**1aii**	**1aiii**	**1bi**	**1bii**	**1ci**	**2ai**	**2aii**	**2bi**	**3ci**	**N**
Coastal Environment (CE)											
Sea information	1	-	-	-	4	-	-	-	3	-	1
Land use	1	-	-	-	-	-	1	-	-	-	-
Atmospheric information	-	-	-	5	-	-	-	-	1	-	-
Climate data	-	-	2	-	-	-	-	-	-	-	-
Socio-economic development (S-ED)											
Human development indicators	-	-	-	-	-	2	-	-	-	-	-
Demography	-	9	-	-	-	1	-	-	-	-	-
Economy	-	3	-	4	-	10	-	-	-	1	-
Education	3	2	-	-	-	1	-	-	1	-	-
Health	-	-	-	5	-	-	-	-	-	-	-
Pollution	-	-	-	5	-	-	-	-	1	-	-
Hazards-risks (*H-SR*)											
Geological hazards- risks (e.g., earthquakes)	2	-	-	-	-	-	-	1	-	-	-
Climatic risk (e.g., heatwaves, extreme winds)	3	-	-	-	-	-	-	-	-	-	-
Flood risk (e.g., fluvial, pluvial)	1	-	-	-	-	-	-	-	-	-	-
Extreme sea level	3	-	-	-	-	-	-	-	-	-	1
Accidents/pandemic	-	-	-	-	-	-	2	-	-	-	-
Coordination/cooperation (C-C)											
Investments	-	-	-	-	-	3	-	-	-	-	-
Added value of economic activities	-	-	-	-	-	3	-	-	-	-	-
Availability of scientific staff	-	-	-	-	-	1	-	-	-	-	-
Program statements of the municipal authority	-	-	-	-	-	-	1	-	-	-	-

Due to the location and geomorphology of the area and the intense economic activities, there are risks to the coastal natural and human environment. First, there is a moderately high seismic risk: 51 earthquakes with a magnitude greater than 5 ML were recorded in the period 1964 - 2020 within a radius of 150 km; the most energetic earthquake (6.3 ML, focal depth 10 km) was recorded on 24/02/1981 (IoG 2020). Secondly, the landslide risk has been classified as 'high' in the western and southern sectors of the municipality (EFAS 2020). Thirdly, 80 % of the population lives and most economic activities take place in an altitude of less than 10 m (ELSTAT 2020); in this area, sea level rise has been estimated as 2.4 – 4.8 mm/yr for the period 1993 - 2019 (Mohamed and Skliris 2022). It is expected that the impacts of extreme weather events affecting the municipality (HNMS 2020) would likely increase in the future (UNECE 2020). There are also other health/safety risks, including industrial accidents and as the recent COVID-19 experience has shown) potential risks from future epidemics/pandemics.

For the development and operation of structures aimed at the coordination and cooperation of the scientific and non-scientific entities involved, the following are noted. Investment trends in public administration, social security, education, and human health and social care are significantly lower than the national average; in comparison, investment in research and development (R & D) and information/communication is greater than the national average (ELSTAT 2020). Interestingly, the performance in most economic activities (ELSTAT 2020) has decreased, although the availability of highly educated population exceeds the national average (EUROSTAT 2020).

It appears that the Elefsina Municipality faces many challenges, particularly involving its coastal environmental (CE) condition and the socio-economic development (S-ED), whereas there also several health and safety risks (H-SR) requiring mitigation and management.

3.1.2 Challenges in thera municipality

The collated information for the area was also evaluated for availability/reliability (Table 4), showing mostly similar results to those of the Elefsina Municipality. Information on the S-ED policy axis is also the most available and provided by aggregated information from the wider area, whereas there is only sparse information on the local CE challenges. The main challenges identified from the

Table 4 Classification of the reliability of available data for the municipality of Thera. For details of the notation in Data Reliability, see Section 2.1

Data Fields	Data Reliability										
	1ai	1aii	1aiii	1bi	1bii	1ci	2ai	2aii	2bi	3ci	N
Coastal Environment(CE)											
Sea	1	-	-	-	1	-	-	-	4	-	3
Land use	1	-	-	-	-	-	1	-	-	-	-
Atmospheric information	-	-	-	-	-	-	1	-	-	-	5
Climate data	-	-	-	-	-	-	2	-	-	-	-
Socio-economic development(S-ED)											
Human development Indicators	-	-	-	-	-	2	-	-	-	-	-
Demography	-	9	-	-	-	1	-	-	-	-	-
Economy	-	3	-	4	-	10	-	-	-	1	-
Education	3	2	-	-	-	1	-	-	1	-	-
Health	-	-	-	5	-	-	-	-	-	-	-
Pollution	-	-	-	-	-	-	1	-	-	-	5
Hazards-risks(*H-SR*)											
Geological hazards- risks (e.g., earthquakes)	2	-	-	-	-	-	-	1	-	-	-
Climatic risk (e.g., heatwaves, extreme winds)	3	-	-	-	-	-	-	-	-	-	-
Flood risk (e.g., fluvial, pluvial)	1	-	-	-	-	-	-	-	-	-	-
Extreme sea level	3	-	-	-	1	-	-	-	-	-	-
Accidents/pandemic	-	-	-	-	-	-	2	-	-	-	-
Coordination/cooperation (C-C)											
Investment	-	-	-	-	-	3	-	-	-	-	-
Added value of economic activities	-	-	-	-	-	3	-	-	-	-	-
Availability of scientific staff	-	-	-	-	-	1	-	-	-	-	-
Program statements of the municipal authority	-	-	-	-	-	-	1	-	-	-	-

available/reliable information for the different policy axes are summarized below.

The municipality of Thera (Fig. 1) includes the islands of Thera, Therasia and neighboring islets, has an area of 90.7 Km^2 and a population of 15,550 permanent residents (density of 171/km^2) (ELSTAT 2020). It is a famous archaeological site and touristic destination, with 525,000 international tourist arrivals at its international airport (SNA) and almost 750,000 cruise passenger arrivals at the Athinios Ferry Port (AFP) in 2018 (SETE 2018). The very high imbalance between the permanent and seasonal population, creates large challenges for the municipality, particularly associated with the island's carrying capacity, waste management and social and health services.

Land uses in 2018, according to the CORINE codification, are associated with discontinuous urban fabric and transport networks, meadows, vineyards and other agricultural uses, whereas there are also areas with little or no vegetation (YPEN 2018). Changes in land uses (in about 50 acres) have been recorded in the period 2012-2018, related mainly to urban development, conversions of grassland to arable land, greenhouse construction and increased mining activity (Copernicus 2021).

The quality of Thera's bathing waters, monitored according to the EU Directive 2006/7/EC (EC 2006), has been assessed as 'excellent'. The ecological situation has been characterized as 'high' in the coastal waters of the Thera caldera (SSW 2020); in its deeper waters, however, increased concentrations of heavy metals have been reported which have been attributed to leakages from the cruise ship MS 'Sea Diamond' shipwreck sunk in 2007 (TUC 2011). Due to the dense maritime traffic in the port of Santorini (AFP, Fig. 1), high atmospheric particulate concentrations have been recorded (NABU 2020).

Economic development has been mostly associated with tourism and has had large effects on the local community. In addition to the increase of the permanent population by almost 62 % since 1991 (ELSTAT (2020), there has been a very high increase in 3S seasonal tourism that challenges the beach carrying capacity, infrastructure and services (Monioudi and Velegrakis 2022). Interestingly, although the tourism industry is booming, the Human Development (HDI) and Gender Development (GDI) indexes were estimated for 2019 as 0.832 and 0.956, respectively, lower that national averages of 0.887 and 0.968 (Global Data Lab 2020; UNDP 2022;).

At the same time, life expectancy at birth was 82.7 years (national average 82.1 years) with a relatively good population health compared with EU average (EUROSTAT 2020), despite the low capacity in health specialists/infrastructure (ELSTAT 2021 pers. comm).

Hazard and risks for coastal natural and human environment are mainly related to the following. First, there is considerable seismic activity within a radius of 50 km, with 33 seismic events with an average magnitude of 4.2 ML (Richter scale) and a focal depth of down to 50 km recorded in the period 1964-2020; in addition, there were 24 events with a magnitude greater than 5 ML within a radius of 150 km with an average magnitude of 5.3 ML and average focal depth of 39 km (IoG 2020). Secondly, there is a considerable risk of increased volcanic activity which may affect significantly the environmental conditions (Tassi et al. 2013; Barberi and Caparezza 2019). Thirdly, due to Thera's geomorphology and geological setting there are many areas (e.g., Oia, Therasia) where the landslide risk is 'high' or 'very high' (EFAS 2020), whereas there is also a considerable Tsunami risk (Batzakis et al. 2020). Fourthly, there are risks from severe weather phenomena (HNMS 2020) and coastal erosion, particularly for the low elevation 'sandy' coasts with strong economic activity (e.g., Ćulibrk et al. 2021).

For the development and operation of structures aimed at the coordination and cooperation of the scientific and non-scientific bodies involved, the following are noted. There is an increased investment in public administration, social security, education, and for activities related to human health and social care; in comparison, investment for 'Research and Development' and 'Information and Communication' is lower than the national average (ELSTAT 2020). Finally, the availability of scientific staff in proportion to the population, although increasing, is still below the national average (EUROSTAT 2020).

In summary, the Thera Municipality also faces many challenges, particularly involving its development model (3S and cruise tourism) and its implications for the municipality socio-economic development (S-ED), and the management of hazard and safety risks (H-SR).

3.2 Decision maker prioritization (Phase III)

3.2.1 Elefsina

On the basis of the presented information, the questioned municipal policy makers followed a pairwise comparison to prioritize the policy axes they considered more important. This exercise ascribed a 'weight' on each of the four coastal policy axes, as follows: coastal environment (CE), 17.4 %; socio-economic development (S-ED), 20.2 %; addressing risks to human safety and health (H-SR), 18.1 %; and coordination-cooperation (C-C), 44.3 %.

The findings show that the municipal authority perceives the coordination-cooperation challenges as the most significant. The municipal authority declared as its aim to plan and implement policies towards achievement of the Sustainable Development Goals (SDGs) (UN 2015). It has made efforts to advance the development/operation of relevant municipal structures and its cooperation with stakeholders to address local challenges. Implementation of policies targeting the local economic and social development is ranked second from the top, an expected choice as most municipal economic activities have shown a negative change since the 2010 economic crisis. Addressing the potential risks to human environment, including planning and implementing measures to mitigate/manage risks ranked third whereas, interestingly for a coastal municipality with many local challenges in its environmental status (Section 3.1), the CE policy axis received the least consideration; it appears that local decision makers perceive the study and protection of the coastal ecosystems to be a matter for wider regional/national policies.

The importance assigned by the municipal authority to the different policy actions (Table 2) was also gauged, with the responses for each action normalized by the above policy axis prioritization (Section 2.2); these are summarized below in decreasing prioritization ranking (Fig. 3 and Table 5). The highest ranking was assigned to the need for additional relevant research (RSR, 15.5 %), suggesting that the municipal decision-makers consider

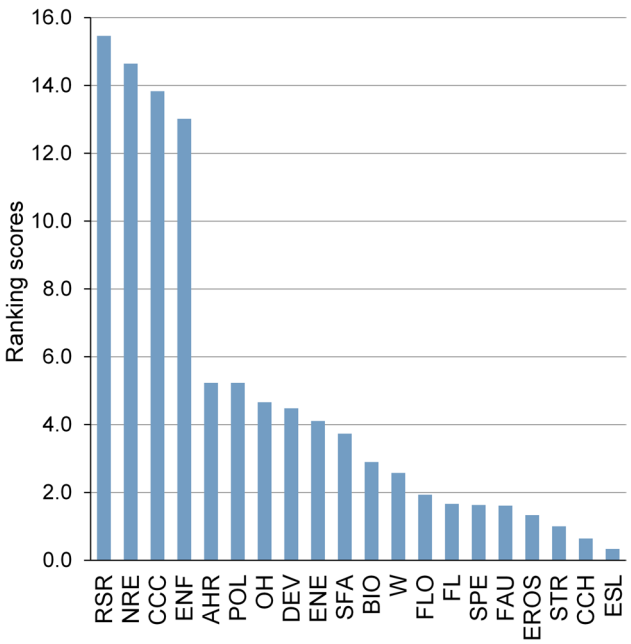

Fig. 3 Municipality of Elefsina: Prioritization of coastal policy actions (for acronyms see also Table 2)

Table 5 Prioritization of coastal policy actions in Municipalities of Elefsina and Thera

Acronym	Policy Action	Elefsina	Thera
FLO	Study/monitoring of (wild) flora	1.9%	0.9%
FAU	Study/monitoring of (wild) fauna	1.6%	0.5%
BIO	Biodiversity assessment and protection measures	2.9%	1.8%
CCH	Improved knowledge/assessment of climate change impacts; adaptation planning	0.6%	5.0%
W	Study of water resources and systems; measures of rehabilitation/preservation	2.6%	4.1%
AHR	Improving access to the coastal recreation/leisure opportunities; improvement of health and social care services	5.2%	5.7%
POL	Study of environmental pollution; protection measures	5.2%	4.7%
ENE	Activities related to energy production	4.1%	6.2%
SFA	Local policies for shipping, fisheries and aquaculture	3.7%	3.1%
DEV	Demographic/education issues; promotion of new economic activities	4.5%	5.2%
FL	Assessment of flood events; flood protection works	1.7%	5.5%
ESL	Assessment of extreme sea levels, adaptation measures	0.3%	3.4%
STR	Assessment of storm wind events; adaptation measures	1.0 %	5.5%
EROS	Assessment of coastal erosion; protection measures	1.3%	10.3%
OH	Assessment of other hazards/risks; protection measures	4.7%	13.0%
CCC	Improvement/upgrading of administration structures; coordination/collaborations; information services	13.8%	7.1%
ENF	Preparation of legislative/regulatory work; distribution of financial and human resources	13.0%	4.6%
SPE	Appropriate measures for protection of endangered, threatened species; invasive species assessments	1.6%	0.4%
NRE	Robust ecosystem restoration and resilience projects; beach replenishment	14.6%	6.7%
RSR	Further research on the above issues	15.5%	6.2%

that they need additional (primary) information to inform their actions. Policy actions related to environmental restoration (NRE), regarded as C-C policy axis actions, were also ranked high (14.6 %), due probably to the long heritage of intensive industrial activities in the area; major issues identified were, for example, related to the removal of (18) ship wrecks and decommissioned ships from the adjoining coastal waters of the Gulf of Elefsina and the upgrade/remodeling of public spaces. With regard to specific cooperation, coordination and communication policy actions (CCC, 13.8 %), the public administration's work has focused on set goals, such as: promotion of Elefsina as a functional, safe, cultural city; improvement of education (there was increased investment per capita in the period 2015 - 2018); and the promotion of participatory processes in the context of reducing pollution and improving the life quality including through information sharing/communication. Importance was also assigned to the improvement of enforcement of environmental norms (ENF, 13 %) by redistributing financial and human resources, and the need for an improved regulatory framework for effective policy implementation.

The remainder of the policy actions gauged ranked much lower and included actions related to: health/recreation (AHR) (5.2 %), with efforts focusing on upgrading the coastal front and opening up previously restricted to the public areas; the study of pollution (POL) (5.2 %) from human activities and the effectiveness of mitigating actions. Policy actions related to the management of other hazards (OH, (4.7 %) were related to measures to increase the municipality's resilience to seismic activity and potential volcanic air pollution and the promotion of the resilience of the co-existing industrial activity (heavy industry, energy plants, shipbuilding) with the urban fabric.

The municipal authorities also attached significance (DEV, 4.5 %) to the study of the reasons (and potential remediation options) of the decrease in the 0 - 4 years population group and the improvement in the teaching staff/student ratio in the primary/secondary education that falls short of the national average. Actions related to the promotion of renewable energy production (solar, wind, hydraulic, marine, biomass and geothermal) (ENE, 4.1%), as well for the control of the intensive shipping activity in the Gulf of Elefsina and the use of its commercial port were also elaborated (SFA, 3.7 %).

Low prioritization was assigned to actions directly related to the monitoring and restoration of coastal ecosystems, such as: the protection of biodiversity (BIO 2.9 %) and water resources/systems (W 2.6 %), the study/monitoring of the (wild) flora (FLO 1.9 %) and fauna (FAU 1.6 %), the protection of endangered species and the management of invasive species (SPE 1.6 %). Finally,

policy actions related to assessment and mitigation of hazards/risks related to floods (FL 1.7 %), coastal erosion (EROS 1.3%), storms, heatwaves, snowfall/hail (STR 1.0 %), extreme sea levels (SLR, 0.3%) and climate change impacts (CCH, 0.6 %) were assigned very low prioritizations.

3.2.2 Thera

In Thera/Santorini the prioritization weights of the four policy axes assigned by the municipal decision-makers were quite different to those of the Elefsina municipality: Coastal environment (CE), 22 %; Socio-economic Development S-ED, 25 %; Addressing Risks to human safety and health (H-SR), 33 %; and Coordination-Cooperation (C-C), 20 %. Here, the municipal authority perceives the assessment/mitigation of coastal hazards/risks as the most significant challenge. This may reflect a large increase in exposure, due to the strong surge in both the resident population and tourist arrivals. The remainder of the policy axes showed similar prioritization weights (20 - 25 %). The least importance was assigned to the C-C policy axis, in contrast to the findings in the Elefsina municipality.

The responses for the different policy actions (normalized by the above policy axis prioritization) are summarized below in decreasing prioritization ranking (Fig. 4 and Table 5). The highest ranking was assigned to actions related to assessment/management of hazards/risks (OH, 13 %) related to geological hazards (earthquakes, volcanism, tsunamis), transportation/industrial accidents and health epidemics/pandemics. The former, is understandable considering the geological setting/history of the volcanic island (Friedrich 2015) that requires the continuous monitoring of these risks, whereas the others are related to the increasing needs for prevention/management of accidents on land, in the air and the sea which have increased due to the burgeoning seasonal tourism and the COVID-19 experience (e.g., Perillo et al. 2021).

Policy actions related to the assessment/management of the high landslide risk (EFAS 2020) and coastal erosion in the municipality (e.g., Monioudi et al. 2017) ranked also high (EROS, 10.2 %). Strengthening of the efficiency of public administration (CCC, 7.1 %) was also deemed relatively important, with actions planned/implemented to: establish new and/or upgrade existing services (in tourism promotion), upgrade the port operational capacity, and increase synergies with local stakeholders. Emphasis has been also placed on: NRE actions (6.6 %), particularly in relation to the increasing waste management problem; the promotion of actions associated with the ever-increasing energy needs and the assessment of the potential opportunities

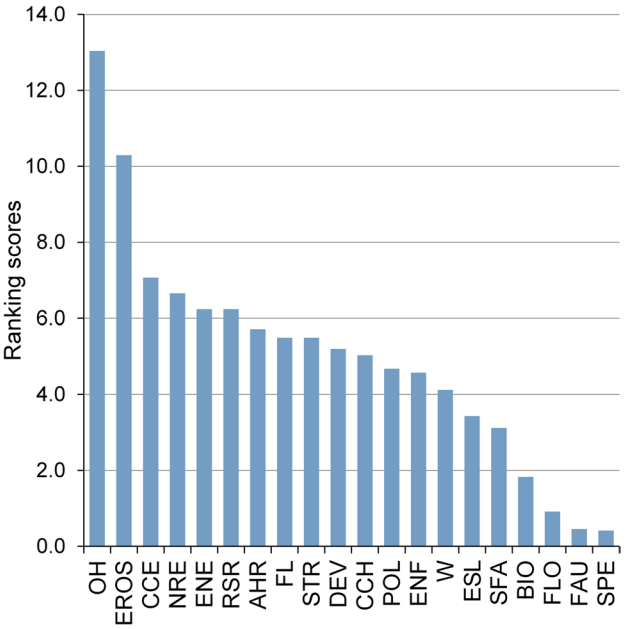

Fig. 4 Municipality of Thera: Prioritization of the 20 coastal policy actions gauged (for acronyms see also Table 2)

in Renewable Energy production (ENE, 6.2 %); and the need for additional relevant research (RSR, 6.2 %) to inform decision making.

Most of the remainder of policy actions achieved lower rankings. Selected actions were related to the social welfare of the population and visitors, e.g., extending accessibility for disabled people over the entire municipality, improvement of public transport, increased access to archaeological sites and other recreation sites and strengthening of the health services to match the needs of the burgeoning tourism (AHR, 5.7 %). Significance was also assigned to policy actions related to: the strengthening of economic activities in general (DEV, 5.2 %) and in shipping (SFA, 3.1 %) in particular through the planning for new marinas and supporting cruise infrastructure; the tackling of pollution (POL 4.7 %); the redistribution of the available relevant financial/human resources (ENF 4.5 %); the protection and management of water resources (W 3.4 %); the assessment/management of extreme sea levels (ESL, 3.4%), as well as the assessment of the impacts of and adaptation planning to climate change (CCH 5.0 %). Finally, the local decision makers prioritized low the protection of the biodiversity (BIO 1.8 %), the study/monitoring of the (wild) flora (FLO 0.9 %) and fauna (FAU 0.5 %), and the protection of endangered species and the management of invasive species (SPE 0. 4 %); this may be due to the generally good environmental status of the municipality which drives a policy maker perception that there is no need for further action.

4 Discussion

4.1 Comparison of the policy priorities of the two municipalities

The framework implementation in the two municipalities has revealed major differences in policy prioritization (Fig. 5). The industrial/urban character of Elefsina and its immediate proximity to similar neighboring municipalities of Metropolitan Athens requires synergies and integrated/common approaches to the coastal challenges and realistic, short-time timetables to address them; therefore, the 'Coordination-Cooperation' (C-C) policy axis appears as the highest priority. In comparison, the importance of this policy axis for the decision makers in the Thera municipality is the lowest, due its insular character and the 3S tourism dominated economic activities. In Thera, the highest policy priority is associated with addressing hazards/risks (H-SR), due probably to the municipality population dynamics, its geological situation/history and the increasing exposure of the coastal populations, assets and major economic activities to natural hazards/risks. Thera has, in recent decades, become a top international tourist destination, which increases the prioritization of policies to address risks to human safety and health. Its insular setting requires higher self-reliance for the prevention of and the response to natural hazards/emergencies than that in Elefsina Municipality that can rely on the extensive infrastructure/services of the metropolitan Athens area.

The remainder of the policy axes (CE) and (S-ED) appear to rank rather similarly in terms of prioritization (Fig. 5). The S-ED policy axis (social welfare policies and measures to support economic activities) ranks second in both municipalities, although Thera appears to put more emphasis on this policy axis than Elefsina; this could again be explained by its insular setting that demands local focus and the need to protect and expand services supporting its major economic resource, i.e., its (international) tourism industry. Interestingly for coastal municipalities, the ÇE policy axis ranks low in both areas, although for different stated reasons. In Elefsina, the monitoring and protection of the (degraded) coastal ecosystems is perceived as a challenge that can only be addressed through integrated efforts in a wider geospatial scope (beyond the borders of the municipality), whereas in Thera there is a perception that its coastal ecosystems have a good ecological status and, thus, policies should focus on addressing other, more immediate, environmental problems/risks.

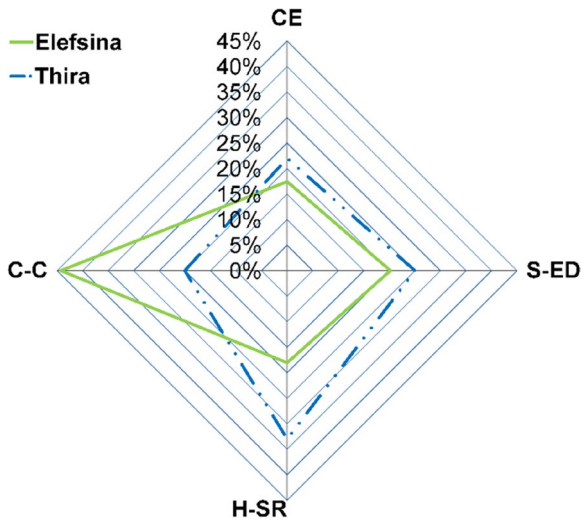

Fig. 5 Comparison of policy axis prioritization in the Municipalities of Elefsina and Thera

In terms of the prioritization of the specific policy actions gauged, there are interesting differences in their prioritization in the two municipalities (Table 5), some of which are highlighted below. There is a large difference in the focus of the Thera Municipality on policy actions for the assessment/management of the impacts of natural hazards, probably due to its high exposure and geological history (Monioudi et al. 2017; 2021; EFAS 2020; HNMS 2020; Batzakis et al. 2020), as well as its limited capacity to respond to disasters from extreme weather, floods, erosion, landslides, fires due to its insular character. Elefsina Municipality prioritizes the needs for regulation and financial/human resources (ENF, 13 %) and environmental restoration policy actions (NRE, 14.6 %) higher than the Thera Municipality (ENF 4.6 % and NRE 6.7 %, respectively), due, probably, to the different development model and history of the two municipalities. In addition, the Elefsina's policy action prioritization is topped by the need for more local relevant knowledge/information (RSR. 15.5 %).

Finally, a major finding of the framework implementation in both these different municipalities has been the limited focus on policy actions directly relevant to the improvement of knowledge on climate change impacts and the planning for appropriate adaptation measures. This is particularly true for Elefsina Municipality, where CCH policy actions (0.6 %) rank almost at the bottom of the prioritization ranking, whereas for Thera municipality such actions, although of higher prioritization (CCH, 5 %), still rank at the lower half of the prioritization list (Figs. 3 and 4 and Table 5).

As climate change and its impacts are most significant threats to coastal areas (UNFCCC 2020), it is noteworthy that targeted policy actions have not been prioritized higher in these two coastal municipalities. Therefore, it is interesting to review this prioritization on the basis of a more detailed assessment of the projected climate change hazards/impacts than that based on the previously

available information that was presented to the policy makers (Phase II, Fig. 2).

4.2 Climate change hazards and impacts

The climatic changes expected to impact mostly the coastal populations, infrastructure/assets and economic activities in northeastern Mediterranean are related to the increases in the mean and extreme sea levels and temperatures and associated droughts and wildfires (e.g., UNECE 2020). In Elefsina, future extreme sea levels (ESLs), exacerbated by the relative mean sea level rise (RSLR), could flood the low-lying coastal urban/industrial areas causing damages and operational disruptions including to the Elefsina port and associated inland transport infrastructure. The 1 in a 100 years extreme sea level (ESL_{100}), a common design threshold for coastal/port protection, will increase from its baseline (1980 - 2014) value of about 1.3 m by 1.17 m by 0.22 - 0.33 m and 0.53 - 1.08 m depending on the IPCC and ice-melt scenarios (Hinkel et al. 2014) by 2050 and 2100, respectively (Vousdoukas et al. 2017; Velegrakis et al. 2023). These increases would require upgrades in the coastal/port protection schemes designed for the previous/current extreme levels.

Future extreme temperature events may also create significant challenges for the urban population and economic activities; for example, seaport operations (and possibly, the infrastructure itself) could be seriously impacted due to increasing health and safety concerns and energy needs (and costs) for cooling (e.g., Monioudi et al. 2018). Heat wave events will increase in both magnitude and frequency (UNECE 2020). Heat waves having the magnitude of the baseline 1 in a 100 years heat wave (the mean of the 1976-2005 period) have been projected to occur (Dosio et al. 2018): every 19 years under the 1.5 °C Special Warming Level (SWL) scenario (expected to be reached by the 2030s, IPCC (2018)); every 7 years under the 2 °C SWL (expected by the 2050s); and every 5 years under the 3 °C SWL scenario (expected in the beginning of the next century). It is also projected that the 100-year heat wave will approximately double in magnitude under the examined scenarios. Such hazard projections suggest a need for greater focus on the potential climate change impacts than that shown in the prioritization of the Elefsina Municipality decision makers; detailed assessments and requisite policy actions are required to meet these challenges.

In the case of Thera, although high significance was assigned to the H-SR policy axis and relevant actions (Fig. 5 and Table 5), climate change (CCH) actions received a low prioritization. It appears that although the municipality decision makers recognize the challenges posed by natural hazards, they do not appreciate to the same degree their potential exacerbation due to climate change and, thus, the need for adaptation. In order to get further insights in this matter, the potential impacts of climate change on coastal erosion (a prioritized policy action by the policy makers EROS, 10.3 %) were studied in more detail. As the 'sandy' coasts (beaches) form the major natural resource of the Thera 3S tourism (Monioudi and Velegrakis 2022), the analysis focused on beach erosion.

The geo-spatial characteristics (i.e., beach length and beach maximum width (BMW), area, sediment type) and human development features (i.e., the density of backshore assets) of all (30) Thera/Santorini beaches were recorded on the basis of the (2019-2020) images and other related optical information available in the Google Earth Pro application (Monioudi et al. 2021). The subaerial ('dry') beaches were digitized as polygons, with their: (i) landward boundaries defined by either backshore natural features (vegetated dunes and/or cliffs), or permanent artificial structures (e.g., coastal embankments, roads and buildings); and (ii) seaward boundaries defined by the shoreline. There are obvious, but unavoidable, constraints stemming from the accuracy/resolution and geo-referencing of the satellite images from which the information has been extracted, and the control on the shoreline delimitation by the hydrodynamic conditions during which image collection took place (e.g., Chatzipavlis et al. 2019).

Beach retreats under climate change were projected using seven 1-D (cross-shore) morphodynamic models in two ensembles, i.e., 3 analytical models (Bruun (Bruun 1988), Edelman (Edelman 1972) and Dean (Dean 1991)) and 4 numerical models (SBEACH (Larson and Kraus 1989), Leont'yev (Leont'yev 1996), XBeach (Roelvink et al. 2010) and the Boussinesq model, whose hydrodynamic component involves high-order Boussinesq equations (Karambas and Koutitas 2002)). This approach was employed as it can provide estimations of beach retreat/erosion at regional level under using minimal, easily obtained environmental information; it addresses limitations stemming from the need of detailed coastal topographic and other environmental information (e.g., Jiménez et al. 2012; Rueda et al. 2017). The ensemble approach enhances the robustness of the findings; given that the sensitivity to different forcing factors and environmental conditions varies among the individual morphodynamic models, their use in ensembles can exploit each model's strengths and mitigate its weaknesses (Sherwood et al. 2022; Simmons et al. 2022).

Two model ensembles were formed to project beach retreat under the relative mean sea level rise - RSLR (3 analytical models) and extreme sea levels-ESLs (4 numerical models), respectively. This approach has gone

through a validation exercise, where the model results were compared with those of physical experiments (Monioudi et al. 2017). This exercise has demonstrated that the ensemble modeling significantly improves the comparison between the projections of beach retreat and the findings from the physical experiments, under both mean sea level rise and extreme sea levels.

Nevertheless, this approach has limitations due to the use of 1-D modeling and the lack of consideration for any artificial and/or natural protection present that can increase beach resilience (Velegrakis et al. 2016; Peduzzi et al. 2022). However, such constraints are: a) inherent in large-scale applications; and b) our methodology aims to provide a broad overview rather than replace detailed modeling studies for individual beaches. In addition, the vast majority of Thera beaches are not fronted at all by beach protection works and, in the few exceptions, these works involve only a small part of the beach length.

These models formed two different ensembles to project beach retreat under the relative mean sea level rise-RSLR (analytical models) and extreme sea levels-ESLs (numerical models), respectively, following the approach described in detail in Monioudi et al. (2017).

The assessment of beach retreats was conducted considering two key factors: (a) relative sea level rise (RSLR), and (b) the occurrence of a 1 in 100 years coastal Extreme Sea Level (ESL_{100}) event which combines storm surge water levels with mean sea and tidal levels, as well as wave set-ups (Vousdoukas et al. 2017), projected for the years 2050 and 2100 under different climatic (RCP4.5 and RCP8.5) and ice mass (ice-melt) change scenarios (e.g., Hinkel et al. 2014).

Projections on the RSLR, tide and ESL_{100} for the 21st century were abstracted from the JRC (Joint Research Centre) database (Vousdoukas et al. 2017). The projections were transformed using as baseline the year 2020, the time period of the digitized beach polygons. Given the spatio-temporal scale of the application, the input data of the models could not be based on *in situ* measurements. Therefore, the models were set up using a plausible range of environmental conditions (i.e., combinations of different beach slopes, wave conditions and sediment sizes) producing a range of retreat projections. The 50th and 90th percentiles (i.e., the median value and the value that 90 % of the estimates are lower, respectively) of the model projections were then compared with the recorded beach maximum width (BMW) to assess the impacts on the 'dry' beach width and the backshore assets/infrastructure (see also Monioudi et al. 2021).

The projections (Fig. 6) suggest a relative sea level rise (RSLR) of 0.28 m for 2050 under the RCP8.5 high ice-melt scenario. Such rise could be quite impacting: on the basis of the high (90thpercentile) projections of the (analytical) morphodynamic modeling, more than half of the island beaches (about 53 %) will permanently retreat by 50 % of their recorded BMWs. For the year 2100 under the RCP4.5 high ice-melt scenario, a RSLR of 0.7 m will force irreversible beach retreats of about 22 m, based on the 90thpercentile of the estimates, causing up to 83 % and 57 % of the beaches to retreat by 50 % and 100 % of their current BMWs. In comparison, the RCP 8.5 scenario will be catastrophic, as the projected RSLR of 0.79 – 1.07 m will result in 'sandy' coast retreats between 16.6 and 33.7 m under the median (50thpercentile) and the high (90thpercentile) projection, respectively, causing the 23 and 73 % of the Thera beaches to retreat by distance equal to or greater than their present BMWs. In terms of asset exposure, 23 and 64 % of the beaches presently fronting assets are projected to be overwhelmed. Many of these beaches lack the accommodation space to retreat landwards and, thus, will also suffer coastal squeeze without appropriate beach replenishment.

Regarding the impacts of extreme sea levels, the $ESLs_{100}$ in 2050 under RCP8.5 will range between 1.3 (medium ice-melt scenario) and 1.4 m (high ice melt scenario), resulting in storm-induced shoreline retreats of between 26 (median projection) and 42.4 m (high projection, 90th percentile), respectively. The median projections will induce (temporarily) total erosion/inundation of 70 % of all Thera beaches (59 % of beaches fronting assets) and the latter of 80 % of the beaches (73% of beaches fronting assets) (Fig. 6). In 2100, impacts will considerably worsen. Even under the RCP4.5 medium ice-melt scenario and the median projections, 73 % of all Thera beaches will retreat more than their current BMWs (64 % of beaches fronting assets), at least temporarily, whereas under the RCP8.5, 93 % of the beaches (91 % of beaches fronting assets) will be overwhelmed according to the high model projections. Even if the beaches might eventually recover, there could be considerable damages/losses for their backshore ecosystems, infrastructure/assets.

It should be noted that some processes have been inevitably neglected in the modeling, including: cumulative storm impacts, the effects of storm duration/spacing (Callaghan et al. 2008), the absence of lateral sediment exchanges (e.g., Dean and Houston 2016) in the Thera's 'pocket' beaches, uncertainties from the influence of natural and/or artificial coastal protection structures (Stripling et al. 2017), and the implications of nearshore benthic ecosystems (e.g., seagrasses) on wave attenuation (e.g. Peduzzi et al. 2022). Nevertheless, as the sandy shore retreat results are relative to the maximum recorded beach widths, these projections might be considered as conservative and representing the severity of the impacts of climate change on the Thera's coastal natural and

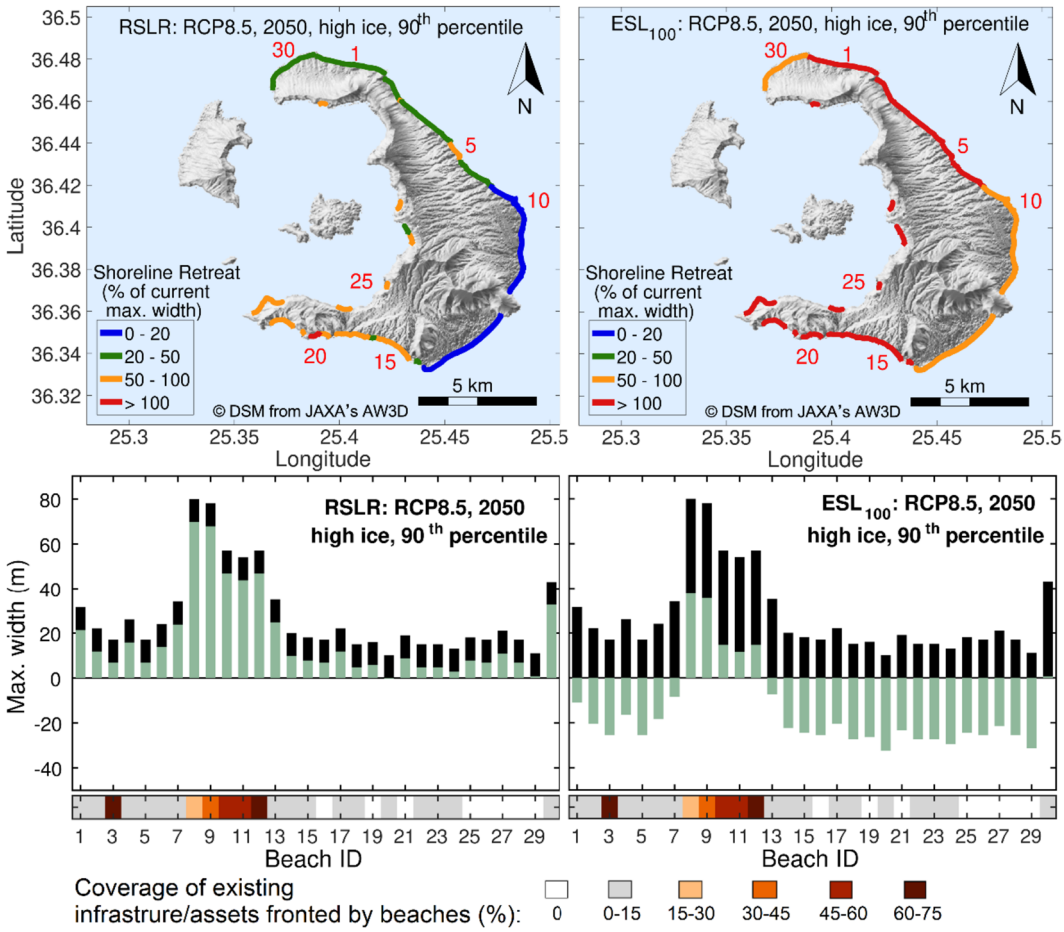

Fig. 6 Thera beach retreats: Percentages of the current BMWs of the 30 Thera/Santorini beaches projected to retreat in 2050 due to (**a**) RSLR and (**b**) the ESL_{100} under the RCP8.5 high ice-melt scenario, according to the 90th percentile of beach retreat estimates of the analytical and numerical model ensemble, respectively. In the lower panels, the current (initial) BMWs (black bars) are compared with those after the projected retreat (green bars) under the RSLR and ESL_{100}; negative values indicate retreats greater than the current maximum widths. Coverage of the first line of backshore assets (as a beach length percentage) is also shown

human environment, requiring a greater focus and effective policies for adaptation.

4.3 Policy and legislation issues

The comparison of policy action prioritization with the current projections of climate change impacts on the coastal municipalities of Elefsina and Thera shows an apparent lack of coherence; the municipalities do not regard climate change as an important enough risk/hazard at this time to spurt targeted coastal policy actions. It appears that there is a mis-match between the perceptions of the local policy makers with the scientific projections, as well as the developing policies/legislation at higher levels of governance (i.e., international, European and national).

In recent years, the policy and legal regimes for disaster risk reduction, prevention, response, management and recovery in coastal areas have been significantly strengthened. In terms of international strategies, policies and plans to which Greece adheres, several Sustainable Development Goals (e.g., the SDGs 13 and 14) of the 2030 Agenda for Sustainable Development (UN 2015), most priorities actions of the 2015 Sendai Framework for Disaster Risk Reduction – SFDRR (SFDRR 2015) and many policies of the Regional Climate Change Framework for the Mediterranean Marine and Coastal Areas (UNEP 2016) strive to build resilience to and reduce disasters from climatic hazards, including from coastal floods and heatwaves. Other international instruments of relevance include the 1992 UN Framework Convention for Climate Change - UNFCCC (UNFCCC 1992) and 1992 Convention on Biological Diversity - CBD (CBD 1992) which deals with the conservation of coastal ecosystems which can be impacted by the deteriorating climatic hazards under Climate Change (e.g., by heatwaves and coastal floods). In addition, there is a particularly

relevant international legal instrument with a regional scope. The 2008 Integrated Coastal Zone Management (ICZM) Protocol to the Barcelona Convention (UNEP 2008) prescribes management of the coastal zone in an integrated manner, addressing among others coastal erosion/flooding, responses to natural disasters and spatial planning actions for impact mitigation (e.g., the introduction of coastal development 'set-back' zones, Art. 8.2). However, although Greece has signed the ICZM Protocol has not yet ratified it.

There are also various European policy and legal instruments which explicitly, or implicitly, address issues of relevance to coastal risk mitigation and management and play an important role in facilitating resilience-building in the coastal zone. The 2021 EU Climate Adaptation Strategy CCA (EC 2021a; 2021b) is of particular relevance, not least, because it emphasizes throughout the close nexus between Climate Change Adaptation (CCA), Disaster Risk Reduction (DRR) and resilience, promotes the mainstreaming of climatic adaptation into all future policies and prescribes formulation/implementation of National and Regional Adaptation Plans. However, the policy prioritization ranking in both studied municipalities indicates that this strategy has not yet percolated down to the municipal level.

In terms, of EU legislation, the recent 2021 Climate Law (Regulation (EU) 2021/1119) (EU 2021) is of particular relevance, as it envisages strong action on CCA and resilience-building, as well as related stocktaking, assessment and review starting in 2023. Other EU legislation of particular significance includes: the Water Framework Directive 2000/60/EEC (EU 2000) that aims (amongst others) to protect the coastal waters affected by coastal floods and erosion; the Floods Directive 2007/60/EC (EU 2007) which deals with the assessment and management of floods including under the changing climate; the amended Environmental Impact Assessment (EIA) Directive 2014/52/EU (EU 2014) which requires risk assessments to improve the resilience of large planned (coastal) projects; as well as a European proposal (EC COM 2021) to revise the Trans-European transport network (TEN-T) guidelines that requires 'climate proofing' of the new network infrastructure, The latter is particularly relevant for the Elefsina Municipality the seaport and associated transport network of which forms part of the TEN-T. New detailed 'Technical guidance on the climate proofing of infrastructure in the period 2021-2027 (EC 2021c) has been published, the compliance to which will be required for EU funding, making risk assessment/management an integral part of project planning, development and financing.

There is also legislation aiming at the protection of coastal ecosystems, which although not dealing explicitly with the flood/erosion risk, still necessitates its assessment and management; for example, the Habitats Directive 92/43/EEC (EU 1992) prescribes for the conservation of coastal habitat types and vulnerable species habitats and, thus, there is an implicit requirement for coastal risk monitoring and management. Finally, it is noteworthy that coastal erosion, which ranked high in policy action prioritization in Thera, but not in Elefsina, is considered in several complementary International and European policies and regulatory instruments that prescribe the its assessment, monitoring and mitigation/management under a changing climate (e.g., the 2008 ICZM Protocol to the Barcelona Convention, and the European Water Framework (2000/60/EC), Flood Risk (2007/60/EC) and amended Environmental Impact Assessment (2014/52/EU) Directives.

Within this context, the recent Greek Regional Climate Change Adaptation Plans for the two municipalities are also of significance. In the Attica Region (Region of Attica 2022), relevant actions are referred to the Region's priority sectors and areas. These include: assessment of the climatic impacts/risks, their interactions with the socio-economic factors and their dynamics, prioritization of adaptation actions, evaluation of the effects of the adaptation actions on the level of risk, and assessment of the uncertainties and constraints. In the South Aegean (Region of South Aegean 2022), the policy actions of the Regional Plan mainly concern the achievement of sustainable development goals and the strengthening of resilience in different sectors on the basis of priorities, such as increasing the administrative capacity, knowledge and skills. The priorities are graded as High, Medium and Low according to the score they receive from the calculation based on the effectiveness and benefits of each adaptation action and the overall climate risk.

Generally, there are fast evolving, and interacting, international and EU policies and legislation that try to address the strategic importance of and keep pace with the urgency of resilience building for coastal populations, infrastructure/assets, services and environments. At the same time, effective management of the coastal risks requires concrete actions that, in many cases, can be only mandated by national legislation and local regulation due the significant 'policy space' afforded in the implementation of the international legislative instruments and the EU Directives. However, recent reviews of the relevant Greek legislation have revealed that, in some cases, fragmented and divergent approaches are in place which may lead to further challenges in the effective implementation of the policy objectives in the coastal zone (Balla and Giannakourou 2020; Velegrakis et al. 2021). In the absence of a coherent strategic vision, guiding

frameworks, and capacity to manage, the perceptions of local players become more important (Hanna et al. 2021).

5 Final remarks

The proposed framework presents a new approach to gauge/assess the perceptions and identify the policy priorities of local decision makers for the management of the coastal zone. It takes into consideration various policy axes and actions related to the environmental and socio-economic conditions and their dynamics. Its implementation in two differing coastal Greek municipalities, i.e. the urban/industrial Elefsina and the insular, touristic Thera/Santorini Municpalities showed the following.

First, policy prioritization is characterized by an (understandably) overarching objective to address immediate environmental and socio-economic challenges in short time tables, usually within a time frame of an Administration; this objective is also associated with constraints in appropriate human and financial resources and the reliance on higher governance (regional/national) levels. Secondly, policy axis and action prioritizations are controlled by the local environmental setting and development model, as they represent central perceptions of the challenges (policy axes), and specific needs for actions (policy actions) to address particular challenges in each coastal region. Thirdly, interestingly for coastal municipalities policy actions associated with the study/protection of coastal ecosystems ranked very low, albeit for different stated reasons. Finally, climate change impacts and adaptation, 'defining generational issues' according to the UN General Secretary, have not been prioritized highly in both coastal municipalities (in Elefsina less than in Thera), in contrast to the large impacts and needs for adaptation projected for these areas and the evolving policy and legislation frameworks. It appears that higher efforts should be made in terms of the assessment of climate change impacts, and the dissemination of the assessment results and the relevance of the evolving policy and legislation regimes to the local policy makers.

Abbreviations

ICZM	integrated coastal zone management
LAU	Local Administrative Units
CE	Coastal Environment
S-ED	Socio-economic development
H-SR	Hazards-risks
C-C	Coordination/cooperation
HDI	Human Development Index
GDI	Gender Development Index
SWL	Special Warming Level
ESL	Extreme Sea Level
RSLR	Relative Sea Level Rise
BMW	Beach Maximum Width
CCA	Climate Adaptation Strategy
EU	European
EIA	Environmental Impact Assessment
TEN-T	Trans-European transport network
FLO	Flora
FAU	Fauna
BIO	Biodiversity
CCH	Climate Change
W	Water
AHR	Access Health Recreation
POL	Pollution
ENE	Energy
SFA	Shipping Fishing Aquaculture
DEV	Development
FL	Floods
ESL	Extreme Sea Level
STR	Storms
EROS	Erosion
OH	Other Hazards
CCC	Cooperation Coordination Communication
ENF	Regulation and Enforcement
SPE	Species
NRE	Nourishment Restoration Resilience
RSR	Research

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Authors' contributions

KEK and AFV contributed to the conception, scope and design of the study. Data collection/analysis and the 'interviews' of the local decision makers were performed by KEK. The proposed framework was developed by KEK and AFV. The first draft of the manuscript was written by KEK. AFV contributed to the results interpretation and discussion and wrote sections of the manuscript INM assessed the climate change hazards and impacts, wrote the corresponding sections of the manuscript and prepared the relevant figures. All authors commented on previous versions of the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the first author on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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