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How are European countries planning for sea level rise?

Sadie McEvoy [a,*], Marjolijn Haasnoot [a,b], Robbert Biesbroek [c]

[a] Deltares, PO Box 177, 2600, MH, Delft, the Netherlands
[b] Coastal Dynamics, Fluvial Systems and Global Change, Utrecht University, PO Box 80.115, 3508, TC, Utrecht, the Netherlands
[c] Public Administration and Policy Group, Wageningen University, Hollandseweg 1, 6706, KN, Wageningen, the Netherlands

A B S T R A C T

Sea level rise (SLR) is projected to have severe consequences for people and assets in European coastal areas. Planning for SLR is a critical step to ensure timely and adequate responses. Despite our rapidly increasing understanding of SLR impacts and the need to adapt, few studies have looked at how countries are planning for SLR. We surveyed experts from the 32 European countries with a coastline about how their country is planning for SLR. Our online survey focused on four areas: (1) whether SLR planning exists and at what level of government; (2) which climate information and scenarios are used in planning; (3) what planning horizons and corresponding levels of SLR are used; and (4) how uncertainty in handled and whether high-end sea level rise is being considered in planning. Additionally, we asked experts to assess the status of sea level rise planning in their country. Our results indicate that most coastal countries in Europe are planning for SLR, but 25% still do not. We find that the planning horizon 2100 is most common and many countries are considering around 1m (adjusted for local conditions) of SLR at that point in time. However, there are significant differences between countries, which may lead to unequal impacts, over time. We also find that RCP4.5 and RCP8.5 are the most widely used climate change scenarios, suggesting that countries are considering high-end climate change in planning, although this does not mean they consider high amounts of SLR. Important questions remain about how planning is realized into levels of protection or preparedness and whether the amounts of SLR and planning horizons currently in use will lead countries to act in time.

1. Introduction

Sea level rise (SLR) is projected to have severe consequences for people, assets and ecosystems in coastal areas worldwide. Low-lying and densely populated regions are at especially high risk (IPCC, 2019). In Europe, countries have varying degrees of exposure and vulnerability to SLR, depending on the local relative SLR and storm surges, topography, land use, and existing flood defenses or other adaptation measures. At present, almost 50 million people in Europe live in the low elevation coastal zone (LECZ, Table 1) and more than 200 million people live within 50 km from the coastline (Vousdoukas et al., 2020). The majority of the people (70%) living in the LECZ are located in the Netherlands, Germany, UK, Italy, Spain, and Russia. The land area in the LECZ is approximately 470,000 km^2 and the total European coastline is 212,000 km. Countries often have some forms of protection against coastal flooding, but these range from protection against events occurring once in 15 years to once in 100 years, or in 1000 years, in the exceptional case of the Netherlands (Scussolini et al., 2016; Tiggeloven et al., 2020). Current trends indicate that migration toward coastal zones is continuing and is projected to further increase in the future (Neumann et al., 2015).

Recent studies have found that in Europe, coastal flood damage costs could increase 2 to 3 orders of magnitude by the end of the century, depending on the rate of SLR and on socio-economic developments (Vousdoukas et al., 2018). The largest share of coastal flood damages is expected in a few countries: the UK, Germany, France, Italy, the Netherlands, and Belgium (Lincke and Hinkel, 2018; Vousdoukas et al., 2018). Still, for countries like Cyprus, Norway, Ireland and Denmark, coastal flood damages could rise to 5% or more of national GDP by 2100 (Vousdoukas et al., 2018). Meanwhile, the annual number of people exposed to coastal flooding is projected to increase 15-30-fold by 2100, in the UK, Italy, and Croatia, among other European countries. Marseille, Naples and Athens are among the top 20 cities worldwide where the expected annual flood damage increases most by 2050 (in relative terms compared with 2005), if adaptation only maintains present defense standards (Hallegatte, Green, Nicholls, & Corfee-morlot, 2013). The impacts of coastal flooding are projected to accelerate after 2050 (Vousdoukas et al., 2018).

Across Europe, countries, regions and cities have been responding to SLR since the mid-20th century. In some areas, high protection standards against coastal flooding are already in place to protect against the 20–100 year events (Scussolini et al., 2016; Tiggeloven et al., 2020; Vousdoukas et al., 2018). Coastal defenses such as the Thames and Maeslant barriers built in the 1970s–1980s, were designed for a SLR up

* Corresponding author.
E-mail address: sadie.mcevoy@deltares.nl (S. McEvoy).

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to 30–40 cm, beyond which they will have reduced performance or additional measures are needed. Well known cases of SLR planning include the Venice's MOSE system (Munaretto et al., 2012), the UK's Thames Estuary (Ranger et al., 2013), the Netherlands' Delta Programme (Van Alphen, 2016; Bloemen et al., 2018) and the more recent flood proofing of the Hafencity area in Hamburg (Aerts et al., 2009; Huang-Lachmann and Lovett, 2016; Jacob, 2015). While these cases stand out as well-known and well-studied adaptation plans, there is limited information on the SLR planning and policies for most countries in Europe (Biesbroek and Delaney, 2020; Losada et al., 2019).

Planning for SLR is critical to anticipate future changes and start implementing measures at the most suitable time (Baills et al., 2020). Planning for SLR refers here to the (range of) possible future(s) governments consider to reduce the impacts, and or take advantage of new conditions as a result of climate change. These are often codified in guidelines, standards and protocols. If and how countries are planning for SLR and implementing these plans depends not only on biophysical conditions of a coastal region, but also on a range of socio-political and economic dimensions that together determine the solution space available in a given country context (Marjolijn Haasnoot et al., 2020).

So far, only a few comparative studies have looked at national level adaptation to SLR. In a study conducted more than 10 years ago, Toll et al. (2008) showed that countries along European coasts were not particularly aware of SLR and were hardly planning adaptation, with a few exceptions, such as the UK, Germany, Netherlands. A recent report by the OECD shows that most European countries are progressing in information provision and are regularly monitoring and evaluating their SLR policies, but are often lacking dedicated instruments and national funding schemes to implement measures (OECD, 2019). So far, however, it is unclear how and to what levels of SLR countries are preparing. Our overarching research question is therefore *how are countries in Europe planning for sea level rise?* We focus on four research questions:

Table 1
Characteristics of European countries with a coastline. LECZ is commonly defined as the contiguous and hydrologically connected zone of land along the coast and below 10 m of elevation (Lichter et al., 2011; McGranahan et al., 2007).

Country	ISO	Coast length (km) (1)	Sea(s) (1)	WB income category (2)	2020 population in LECZ (3)	Land area in LECZ (3)	Protection level (flood return period, in years) (4)	
							Min	Max
Albania	ALB	362	Mediterranean	Upper middle	292,914	1,636	22	34
Belgium	BEL	66	North	High	2,187,912	3,867	150	150
Bosnia and Herzegovina	BIH	20	Mediterranean	Upper middle	406	4		
Bulgaria	BGR	354	Black	Upper middle	86,889	309		
Croatia	HRV	5,835	Mediterranean	High	99,513	1,420	39	66
Cyprus	CYP	648	Mediterranean	High	64,337	180		
Denmark	DNK	7,314	Baltic and North	High	1,395,796	11,641	44	175
Estonia	EST	3,794	Baltic	High	169,805	4,646	39	43
Finland	FIN	1,250	Baltic	High	548,846	9,231	39	48
France (Excl. territories outside Europe)	FRA	3,427	Atlantic and Mediterranean	High	2,613,075	13,675	41	80
Germany	DEU	2,389	Baltic and North	High	3,521,266	20,688	60	300
Greece	GRC	13,676	Mediterranean	High	725,188	6,974	39	50
Iceland	ISL	4,970	Greenland and N. Atlantic	High	52,102	3,748	39	112
Ireland	IRL	1,448	N. Atlantic	High	329,117	3,009	39	63
Italy	ITA	7,600	Mediterranean	High	4,432,035	17,136	44	81
Latvia	LVA	498	Baltic	High	794,768	3,814	40	41
Lithuania	LTU	90	Baltic	High	89,328	1,026	41	41
Malta (incl. Gozo)	MLT	253	Mediterranean	High	6,903	23		
Monaco*	MCO	4	Mediterranean	High				
Montenegro	MNE	293	Mediterranean	Upper middle	9,393	107	17	17
Netherlands	NLD	451	North	High	12,223,303	23,778	300**	30.000**
Norway (incl. islands)	NOR	83,281	North and N. Atlantic	High	179,853	7,300	39	43
Poland	POL	440	Baltic	High	874,831	5,045	44	112
Portugal	PRT	1,793	N. Atlantic	High	331,169	2,200	41	313
Romania	ROU	225	Black	Upper middle	201,122	6,779		
Russia	RUS	37,653	Arctic and N. Pacific	Upper middle	3,465,958	265,049	39	165
Slovenia	SVN	47	Mediterranean	High	27,228	25	78	78
Spain	ESP	4,964	N. Atlantic and Mediterranean	High	3,595,313	6,498	40	257
Sweden	SWE	3,218	Baltic	High	831,896	12,607	39	77
Turkey	TUR	7,200	Mediterranean and Black	Upper	2,448,378	7,703	16	181
Ukraine	UKR	5,618	Black	Lower middle	858,616	10,664		
United Kingdom	GBR	12,429	North and N. Atlantic	High	5,391,670	18,294	45	74
Total		**211,610**			**47,848,930**	**469,076**		

*The size of Monaco is too small to be captured accurately in the 1 × 1 km grid used for the analysis.
(1) https://www.cia.gov/library/publications/the-world-factbook/fields/282.html.
(2) https://datahelpdesk.worldbank.org/knowledgebase/articles/906519.
(3) Estimations based on elevation and land use map: Elevation map from the multi-error-removed improved-terrain digital elevation model, MERIT DEM10 at 30 arcsecond resolution, approx. ~1 km at the equator. Population for 2020 derived from wordpop.org.
(4) Scussolini et al. (2016) and Tiggeloven et al. (2020).
** Alphen, J.A. (2016) The Delta Programme and updated flood risk management policies in the Netherlands. J. Flood Risk Management (9) 310-319.

1. Does SLR planning guidance exist in countries and at what level of government?
2. Which sources of climate information and which climate change scenarios are used to inform SLR projections and planning?
3. What planning horizons and corresponding SLR values are used?
4. Whether and how is uncertainty in SLR handled in planning guidance, and is uncertain high-end SLR considered and up to what value and time horizon?

The remainder of this article consists of four sections. Our research methods and materials are presented in Section 2, followed by our results in Section 3 and a discussion of our results, their implications, the limitations of our research methods and concluding remarks, in Section 4.

2. Materials and methods

To collect information on how countries with a coastline across Europe are planning for SLR at the national scale, we developed an online expert survey. This approach was considered most effective as national policy documents, such as national communications (UNFCCC database) and national adaptation plans and strategies (e.g. accessible via the Climate Adapt database), typically provide general information such as the extent, location and potential timing of SLR impacts, but lack specific information on how countries are preparing for SLR. Moreover, it is difficult to systematically and comprehensively identify current planning guidance and policy documents in individual countries, particularly considering the language barrier with most countries and the fact that SLR planning falls under the jurisdiction of different and often multiple government bodies in different countries.

Considering the boundaries of Europe used in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), there are 32 countries in Europe with a coastline. This includes three countries with a coastline exclusively on the Black Sea (Bulgaria, Romania and Ukraine). Table 1 provides an overview of the countries and some of their key characteristics.

2.1. Survey design and data collection

The online survey consisted of two sections, the first collected information about the respondent and the basis of their response, the second section comprised open ($n = 5$) and closed ($n = 8$) questions. The second section of the survey addressed four topics. First, whether planning for SLR occurred in the country and whether there are planning guidelines at the national, regional or local level. Second, what sources of climate information and scenarios are used for SLR projections and planning in the country. Third, which time horizons and levels of SLR are used in planning for the mid- and long-term. Fourth, whether and how uncertainty is addressed in SLR projections, and separately, whether uncertain high-end sea level rise from accelerated mass-loss from Antarctica and Greenland is considered. The full survey can be found as SM1.

While the survey focused on four main topics, we were also curious how experts perceived their countries' level of preparedness to SLR. Although it is a purely subjective question, we asked respondents for their impressions of how well their country was preparing for SLR.

The survey was pre-tested by experts in five countries (the Netherlands, United Kingdom, Finland, Belgium and France), after which moderate modifications were made to clarify the questions and refine the response options. The survey ran from January to March 2020. Respondents were contacted by email with an invitation to participate. When we did not receive a response after two weeks, reminder emails were sent. A second reminder was sent after an additional two weeks. For countries with only one response after one month, we looked for and contacted additional respondents.

2.2. Respondents

Respondents were identified, using European project databases, workshop and project contact lists, UNFCCC contact lists, scientific publications, and personal networks. Respondents were selected for their expertise on the topic of SLR planning and represented governments, academic and research institutions and non-governmental organizations. For each country, we aimed for 2–4 responses to minimize response bias. In total, more than 150 individuals from 32 countries were contacted about the survey. 96 potential respondents were invited to participate and 60 responses were received (63% response rate), with at least one response from every surveyed country (100% coverage). There are two or more responses for 23 countries and a single response for 9 countries. 48% of respondents represented government, 22% represented universities, 28% represented research or knowledge institutes and 2% specialized consultants.

2.3. Data analysis

Survey responses were checked for completeness and clarity. In the case of ambiguous responses, incomplete surveys, and inconsistencies in a response or between responses from one country, follow-up emails and phone calls were used to clarify. Sometimes this led to minor corrections to the original survey responses.

For countries where we received two or more responses, discrepancies were present in the data. Most inconsistencies were resolved or explainable through follow-up with the respondents. The source of inconsistencies was typically different perspectives or referring to planning guidance from different agencies. Where possible, we chose to keep differences in responses in the data to illustrate the complexity of the topic in most countries. Where one respondent from a country included values and another respondent did not, we use the values given. Once the dataset of responses was as complete as possible, the responses were analyzed for themes and tabulated accordingly. The summarized responses for all countries are available in SM 2.

2.4. Limitations

Our choice for an expert survey has methodological limitations and implications for the robustness of our findings. One factor is the low number of responses per country, in some cases only one. Additionally, our survey captures the individual respondents' understanding of SLR planning in their country, which is not always straightforward and, in some cases, required a certain level of interpretation by respondents. For instance, while one respondent from a country may interpret a national adaptation strategy that includes SLR as national level guidance, another may feel that the strategy is generic and focused on impacts, thence indicating that there is no dedicated national planning guidance on the topic. While we tried to understand such contradictions through follow up communication, in countries with only one respondent these nuances were not always obvious. Furthermore, the validity of the results relies on ensuring the 'right' individuals participate. Identifying these individuals is particularly challenging, as SLR is handled in different and often multiple entities in individual countries. Finally, using a survey meant that we were limited in the level of detail and country-specific context we were able to capture. We received feedback from some respondents that the questions did not reflect the highly tailored approach to SLR planning in their country, and from respondents in other countries that the questions were more advanced than their current SLR planning approach. Future empirical work would be needed to further corroborate our findings.

Despite these limitations, we feel an important contribution of this study is that all countries in Europe with a coastline are represented by at least one respondent. This proved challenging in some cases, particularly countries with limited planning for SLR. The contributions of countries currently under-represented in the literature are valuable in the exploratory context of this study.

3. Results

This section presents the findings following the structure of the expert survey: organization of SLR planning (3.1), sources of information used in SLR planning (3.2), planning horizons and SLR values considered (3.3.), handling uncertainty in planning for SLR (3.4), and respondents' impressions of preparedness (3.5).

3.1. Organization of sea level rise planning

Our analysis shows that 23 out of 32 European countries have SLR planning. In almost all cases, this planning appears to be organized at the national level. Respondents from 13 countries report that they have planning specifically dedicated to SLR; 11 of these at the national level and 2 at the regional level (Belgium, Germany). The remaining 10 countries address SLR through related planning guidance, laws or strategies, such as flood risk management, climate change adaptation and spatial planning. Most countries with a LECZ population greater than one million (Table 1), have dedicated planning to SLR. Italy, Turkey and potentially Russia are the outliers in this regard, and Ukraine and Latvia have LECZ populations close to one million with no dedicated SLR planning.

Respondents from a quarter of European countries reported that there is no official SLR planning in their country. Some of these countries report that they do have impact assessments or SLR studies, but that these have not (yet) translated into SLR planning. For Russia it is unclear whether or at what level SLR planning is organized.

An overview of how SLR planning is organized by country is provided in Table 2, details in SM2.

3.2. Climate change information and scenarios used in sea level rise planning

We find that the IPCC is the most reported source of climate information used in SLR planning in Europe; respondents from 27 countries indicated the IPCC as a primary source of information. Other sources of information reported are local projections through downscaling and expert judgement (17 and 13 countries, respectively). This is more apparent for countries with dedicated SLR planning (Fig. 1). All but one country with dedicated SLR planning (see section 3.1) reported using more than one source of information.

Consistent with the IPCC being the most used source of information for SLR planning, respondents indicated that the most used scenarios are RCP2.6, RCP4.5 and RCP8.5. Almost every country with SLR planning uses one or a combination of these scenarios. Experts reported that the RCP8.5 is the most widely used scenario (22 countries, 11 with dedicated SLR planning), followed by RCP4.5 (18 countries, 8 with dedicated SLR planning) and RCP2.6 (13 countries, 5 with dedicated SLR planning). Experts in more than half of countries reported using more than one RCP scenario, most often RCP8.5 and RCP4.5. If a single scenario was used, it was RCP8.5. Respondents in 5 countries reported using 'other' scenarios, and respondents in 4 countries reported that no scenarios are used (countries without SLR planning).

Table 2 summarizes the information sources and scenarios used by the country. More details are provided in SM2.

3.3. Planning horizons and sea level rise values used in planning

Respondents were asked what mid- and long-term planning horizons are used in their country, and what SLR value(s) are used for each planning horizon.

Our results suggest that for the mid-term time horizon, 2050 is most commonly used (20 countries, Table 3). However, quite a large number of countries do not use this horizon and 5 countries with dedicated SLR planning (N = 13) report not using any mid-term horizons for SLR planning. In some cases mid-term horizons are not used because of ongoing glacial rebound (e.g. Finland and Estonia) or special circumstances like the Black Sea. In other cases, countries work only with longer time horizons, or horizons are tailored to individual projects (e.g. Sweden, the UK and Ireland). The SLR values reported for mid-term time horizons are typically in the range of 0.15–0.35m, however the full range is 0–0.50m SLR.

Survey responses indicate that long-term time horizons are more used than mid-term ones with 2100 as the most reported time horizon (78% of countries, Table 3). A small minority of countries report using long-term horizons earlier (6) or later (2) than 2100. The range of SLR values for long-term horizons is −1.8m in parts of Iceland to 3m considered by Belgium, however 0.5m–1.0m is the most common range of values. For long-term time horizons broad ranges of SLR values are used within and between countries. The range in values represent increasing uncertainty in SLR after 2050 as well as the spatial variability across Europe and within individual countries. For instance, countries like Spain, Italy, the UK and Sweden consider variation along their coastlines as well as ongoing rebound and subsidence dynamics in their SLR projections and planning. North Sea countries with high vulnerability and early adoption of SLR planning, such as the Netherlands, Belgium, the UK and Germany are among the countries planning for the longest horizons and highest levels of SLR. Other countries with notably long horizons and high levels of SLR are Ireland, Portugal, Denmark and Sweden.

Comparing the SLR values used for 2100, shows remarkable differences across Europe (Fig. 1, Table 3). Some countries with a large population in the LECZ prepare for low amounts of SLR (e.g. Russia, France, Spain, Italy), while other countries, with a similar amount of people in the LECZ prepare for much higher amounts (e.g. Germany, Belgium). These differences could be related to lower storm surges along the Mediterranean resulting in less impact for some countries. Another factor could be the length of coastlines of some countries (Table 1), a longer coastline being inherently more costly and difficult to adapt and protect. On the other hand, countries that prepare for lower SLR already have low protection levels (Table 1, Fig. 1). These differences may lead to unequal impacts across Europe as sea levels rise.

It is worth noting that time horizons and SLR values used for planning are often tailored to individual planning decisions and locations. Respondents from some countries, such as the UK, Ireland and Sweden, noted that planning is so highly tailored to location and planning context, that there is no standard horizon or value used. Instead, decision makers select the one most suitable to their purposes.

3.4. Uncertainty handling and consideration of uncertain high-end sea level rise in planning

When asked whether and how uncertainty in SLR projections is addressed in planning, we find inconsistencies in almost every country with more than one respondent. In most countries (19) at least one respondent indicated that at least one approach is used for dealing with uncertainty. There is significant variability in the approaches that respondents reported. Addressing uncertainty by using multiple scenarios is reported to be used in 16 countries, followed by adaptive plans and planning cycles in 10, and 12, countries respectively. Respondents in 14 countries indicated that more than one approach is used. In 18 countries respondents reported that there is no handling of uncertainty in SLR planning, including 6 countries with dedicated SLR planning. Interestingly, 7 countries indicated an approach for handling uncertainty *and* that uncertainty is not directly addressed in planning guidance. Based on follow-up communication with some of these countries, this apparent contradiction reflects the fact that approaches for handling uncertainty are used in practice but are not mandated in the guidance document.

Experts in 17 countries reported that they are either using or exploring accelerated and uncertain high-end SLR in planning. Of

Table 2
Summary of results relating to how sea level rise planning is organized and which sources of climate information and climate change scenarios are used by each country. In the case of Russia, the respondent declined to answer whether planning exists, but answered other questions. After follow-up it remains unclear what form of planning is in place.

Country	N	Planning level					Scenarios					Information source			
		National	Regional/ Local	Other	None		RCP 2.6	RCP 4.5	RCP 8.5	Other	NA/ None	IPCC	Downscaling	Expert judgement	NA/ None
ALB	2			•		Related laws, strategies	+	+	+			+			
BEL	3		•				•	•	•			•	•		
BIH	1				•						+				+
BGR	2			•		Local flood risk management & spatial planning	+	+	+			+		+	
HRV	3			•		Risk assessment, local planning	+	+	+			+		+	
CYP	2				•	Risk assessment					+	+	+	+	
DNK	1	•						•	•			•			
EST	1			•		Related laws, plans		+	+			+			
FIN	4	•					•	•	•			•	•	•	
FRA	2	•					•	•	•			•		•	
DEU	3		•			Regional mandate in relation to national government			•			•	•	•	
GRC	2			•		Related strategies, plans	+	+	+			+	+	+	
ISL	2	•							•			•	•		
IRL	2	•								•			•	•	
ITA	2			•		Local adhoc planning, no mandate	+	+	+			+	+		
LVA	1				•										
LTU	1			•		National coastal zone management	+	+	+			+	+		
MLT	2				•										
MCO	1			•		City-state related plans	+	+	+			+			
MNE	2				•	Impact assessment				+		+			
NLD	2	•						•	•			•	•	•	
NOR	2	•							•			•			
POL	2	•								•		•	•	•	
PRT	2			•		Related strategies, policies	+	+	+			+	+	+	
ROU	2				•	Academic study					+			+	
RUS	1				?	Unclear response regarding whether planning exists				+		+			
SVN	1				•	Impact assessment		+	+			+	+		
ESP	2	•						•	•			•	•		
SWE	2	•				Tailored to location, time, planning	•	•	•	•		•	•	•	
TUR	1			•		Related laws, guidance					+	+			
UKR	2				•	Impact assessment			+			+	+		
GBR	2	•				Tailored to location, time, planning	•	•	•			•	•		

• indicate responses related to dedicated SLR planning.
+ indicates responses representing projections or non-dedicated planning.

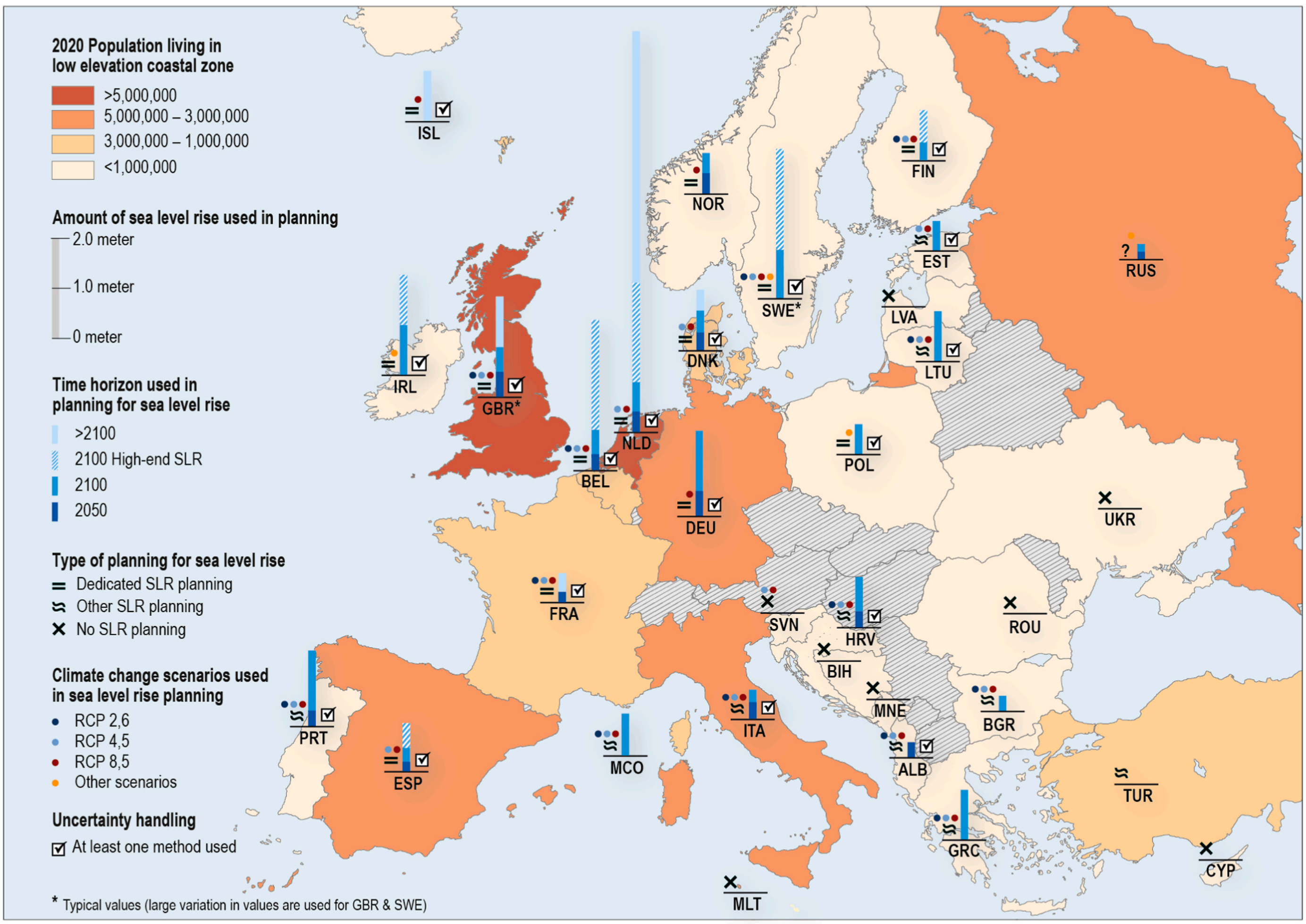

Fig. 1. Map of countries in Europe summarizing: the 2020 population living in the low elevation coastal zone (see Table 1), the amount of sea level rise each country is planning for, at different time horizons, what type of planning is used, which climate change scenarios are employed in sea level rise planning and whether uncertainty handling is accounted for in sea level rise planning. The question mark for type of sea level rise planning in Russia reflects the unclear response on this topic and lack of confirmed planning documents. The amounts of sea level rise and time horizons reflect national guidance, local or project-based levels may differ.

Table 3
Summary of results relating to the planning horizons and levels of sea level rise used in planning, how uncertainty is handled and whether high-end sea level rise is considered, by country.

Country	N	Mid-term horizon				Mid-term SLR level	Long-term horizon				Long-term SLR levels	Uncertainty handling approaches used						High-end scenarios			High-end SLR level
	–	<2050	2050	>2050	NA/ None	(m, 2050)	<2100	2100 & 2100 +	>2100 (exclusively)	NA/ None	(m, 2100)	Mult. Scenarios	Adaptive plans	Planning cycles	Probabalistic	Other	NA/ None	Using/ Exploring	None	NA	
ALB	2		+			*0,16–0,30*				+		+	+						•		
BEL	3		•			0.3		•			0.8–3.0	•	•	•				•			3.0 (2100)
BIH	1				+	No projections				+	No projections						+		+		
BGR	2		+			*Black sea*	+				*0.3*						+			+	*Black sea*
HRV	3		+			*0.15–0.33*		+			*0,3–1.0*	+	+	+	+		+		+		
CYP	2		+			*0.24–0.40*	+				*0.45–0.8 (2080)*			+	+		+	+			*0.8 (2080)*
DNK	1			•		0.35 (2065)			•		0,85 (2110)	•					•	•			1.2 (2150)
EST	1				+	*Land rise*		•			*0.2–0.6*	+		+	+				+		
FIN	4				•	Not used		•			−0.28–0.94	•		•				•			0.24–0.94 (2100)
FRA	2		•			0.2			•		0.6 (2120)			•			•	•			Not quantified
DEU	3		•			0.5 for dikes		•			0.5–1.7	•	•	•							1.7 (2100)
GRC	2		+				+	+			0.5 (2070) planning, 1.0 (2100) strategy						+		+		
ISL	2				•	Not used		•			−1.8–0.99 relative	•		•		•	•	•			0.99 (2100)
IRL	2				•	Not used		•			0.5–1.0 (no defined horizon)	•	•	•				•			1.5–2.0 (no defined horizon)
ITA	2		+			*0.35*		+			*−1.4–0.6 relative*	+						+			
LVA	1																				
LTU	1	+	+					+				+						+			*1.0 (2100)*
MLT	2																				
MCO	1				+	*Not used*		+			*0.2–0.82*						+	+			*SROCC*
MNE	2				+	*Not used*		+			*0.35–1.69*						+	+			*1.69 (2100)*
NLD	2		•			0.15–0.40		•			0.3–1.0	•	•	•				•			2-3 (2100) 5–8 (2200)
NOR	2		•			0.2–0.4	•				0.5–0.8 (2090)						•		•		
POL	2				•	Not used	•				0.6 (2100)					•	•		•		
PRT	2		+			*0.3*		+			*0.5–1.5*	+	+	+				+			*1.5 (2100)*
ROU	2				+	*Black sea*				+	*0.4 (2070)*						+			+	*Black sea*
RUS	1		+			*0.15*		+			*0.2–0.3*						+		+		
SVN	1				+					+							+		+		
ESP	2	•				0.13–0.17 (2045)		•			0.38–0.68	•	•	•	•			•			0.71–0.98 (2100)
SWE[a]	2				•	Not used		•			e.g. 1 (2100) Stockholm	•	•				•	•			e.g. 3m (2100) Malmo
TUR	1				+					+							+		+		
UKR	2	+				*0.15 (2030)*		+			*0.63*						+	+		+	*0.82 (2100)*
GBR[a]	2			•		e.g. 0.06–0.53 (2060)		•			e.g. 0.1–1.15 (2100)	•	•					•			2 (2100)

• indicate responses related to dedicated SLR planning.
+ and italics indicate responses representing projections or non-dedicated planning.
[a] Representative values.

countries with dedicated SLR planning (N = 13), 10 are considering it. In total, 15 countries shared the values that are being considered for accelerated and uncertain high-end SLR. Respondents from 10 countries (3 with dedicated SLR planning) reported not considering high-end uncertain sea level rise, and for the 3 countries with coasts along the Black Sea the topic is not applicable. For most countries considering high-end uncertain SLR, the time horizon 2100 is used. 3 countries reported considering time horizons beyond 2100.

The responses on whether uncertain high-end SLR is considered show some discrepancies within countries. This suggests that there is not a consistent understanding between experts in this survey on what constitutes uncertain high-end SLR. Respondents were asked to share the values used for considering uncertain high-end SLR in their countries. For a number of countries, the values shared are consistent with scenarios such as RCP8.5, based on the IPCC 5th Assessment Report. This suggests that some respondents considered a high-end climate change scenario (RCP8.5) a high-end SLR scenario. Other countries consider higher amounts of SLR due to accelerated mass-loss from Antarctica (e.g. UK, Belgium and the Netherlands), based on more recent scientific publications. Only 8 countries reported using high-end uncertain SLR values above 1 m. Among these are countries with a large population in the LECZ (e.g. Belgium, Germany, the Netherlands, UK). At the same time, several other countries with a large population in the LECZ and a relatively low protection level do not consider SLR above 1 m (e.g. Italy, France, Spain). Denmark is considering higher levels but these are projected around 2150.

3.5. *Respondents' impressions of level of preparedness*

When asked for their impression of how well their country was preparing for SLR, we find a diverse picture across Europe. 30% of all respondents felt that their country was well or very well prepared, 30% felt that their country was reasonably well prepared and 28% felt that their country was not well prepared. The remaining respondents (12%) did not answer the question. In most cases, these were for countries without SLR planning. When comparing the responses by country, the ratios are roughly the same as by respondent, with slightly less than one third of countries being reported as well or very well prepared, reasonably well prepared and not well prepared. For 5 countries (12%), respondents for the same country reported different impressions. However, when there were different impressions, the responses were always similar, i.e. there are no cases where one respondent felt their country was not well prepared and another respondent felt it was very well prepared. In general, respondents working for the government tended to have a more positive impression of their countries' level of preparedness than other respondents. For 2 countries no response was given (Table 4).

Table 4
Summary of surveyed experts perceptions of how well their country is planning for sea level rise.

Country	N	Perception			
		Well/very well	Reasonably well	Not well	No response
ALB	2				2
BEL	3	3			
BIH	1			1	
BGR	2			2	
HRV	3		2	1	
CYP	2		1		1
DNK	1		1		
EST	1		1		
FIN	4	4			
FRA	2	1	1		
DEU	3	2	1		
GRC	2			1	1
ISL	2	2			
IRL	2		2		
ITA	2			2	
LVA	1				1
LTU	1			1	
MLT	2			2	
MCO	1		1		
MNE	2			2	
NLD	2	2			
NOR	2		2		
POL	2		1	1	
PRT	2		2		
ROU	2			1	1
RUS	1	1			
SVN	1				1
ESP	2	1	1		
SWE	2		2		
TUR	1			1	
UKR	2			2	
GBR	2	2			

4. Discussion

SLR is already impacting the coastal areas of Europe and is projected to increase in the foreseeable future. Timely response is of critical importance to reduce future impacts. In this article we presented how surveyed experts from 32 countries in Europe perceive SLR planning in their countries.

Our study contributes several new observations on how Europe is preparing for SLR.

First, our findings suggest that **most countries are planning for SLR** (~75%) and that generally, the most vulnerable countries plan for higher values. These findings are similar to those of a recent OECD study, which showed that the most progress in developing policy guidance and support is being made in countries such as the UK, Germany, Belgium and the Netherlands (OECD, 2019). Earlier studies, such as one by Toll and colleagues (2008), also found that these countries were among the first to plan for climate driven SLR. However, an important new finding of this study is that a number of countries with significant populations in the LECZ are not planning for SLR, and others are only planning for low amounts of SLR (e.g. <0.65m in 2100). This may lead to unequal impacts across Europe.

Second, we find that governments are taking **different approaches** to planning for SLR. Studies on climate adaptation planning more generally, have shown that dedicated policies help to increase issue attention, establish institutional structures and resources, set specific goals and targets, and provide a documented vision of how issues are or ought to be addressed (Runhaar et al., 2018). Planning approaches focusing on mainstreaming adaptation as a cross-cutting issue in other sectors (horizontal) and across scales (vertical), meanwhile, have been shown to help increase shared problem framing, allow for critical alignment with other ambitions (e.g. nature, infrastructure, economic activities), and overall aims to increase coherence, consistency, and efficacy of policy implementation (Jordan and Lenschow, 2010; Peters, 2018). Ideally, both dedicated and mainstreaming approaches can be used together to ensure coordinated responses, but finding an optimum combination is a delicate balancing act (Massey et al., 2014). Moreover, while the majority of countries organize SLR planning guidance at the national level, countries with decentralized policy systems (e.g. Germany, Belgium) have delegated planning to sub-national authorities. A recent study of locally managed estuary flood defense in the UK, found that a balance is needed between local representation and state actors to ensure legitimate policies that align with national and international scale policies and visions (McGinlay et al., 2020) Our findings also show that, broadly, a country's SLR planning approach (i.e. dedicated vs. mainstreamed, national vs. subnational) mirrors the general response to adapt to climate change impacts (Biesbroek et al., 2018).

Although national and regional planning guidance often set the scope of protection standards and SLR values to be considered, respondents noted that planning for SLR is often defined by individual projects. The SLR values being used in the design and implementation of projects are tailored to conditions specific to the project, its location and context. For example, economic investments in critical infrastructure with long functional lifespans and which are difficult to adjust consider different SLR values than measures that can be more easily amended to future conditions. What is being protected by a given measure is also an important factor in the levels considered. Project-based responses to SLR have potential advantages, allowing flexibility to find appropriate and cost-effective measures, while potentially avoiding lock-in.

Third, we find that almost half of countries are planning for an **amount of SLR of 0.15 to 0.35m** for the next 30 years. This suggests that many countries are planning for an amount of SLR that occurs in all SLR projections, independent of the climate or emission scenarios (IPCC, 2019). Measures that address this range of SLR can therefore be considered low-regret. However, if higher amounts or long-term SLR are not considered as well, which our results suggest is the case for some countries with a large population in the LECZ, there is a risk of costly retrofitting on the long term (Gibbs, 2013), or not having enough time to adapt if the rate of SLR accelerates (M. Haasnoot et al., 2020). Conversely, if countries focus solely on long-term horizons (2100), the urgency to adapt may not be felt in time to act. Instead, exploring the flexibility of measures and keeping options open to adapt to high amounts of SLR in the future could avoid regret in investments and maladaptation (Baills et al., 2020; M. Haasnoot et al., 2020). Adaptive planning, already adopted in several European countries (Dutch Ministry of Infrastructure and the Environment and Ministry of Economic Affairs, 2015; Hall et al., 2019; Ranger et al., 2013), could support the trade-off between potentially investing too much too soon, or too little too late. With SLR projections becoming increasingly uncertain after 2050, the need for adaptive planning approaches is clear. Exploring multiple time horizons and SLR scenarios is beneficial for exploring and shaping the solution space over time, in order to seize opportunities, avoid regrets and support timely adaptation (Marjolijn Haasnoot et al., 2020).

Fourth, we find that the **SLR projections used are mainly derived from IPCC information, with RCP4.5 and RCP8.5 being the most used climate scenarios**. This implies two things: that most countries are planning for a range of futures, and thus uncertainty about the future, and that countries are preparing for climate change scenarios beyond the Paris agreement. The latter is further supported by the fact that half of coastal countries in Europe report considering or using high-end SLR in their planning. However, as previously mentioned, the levels considered high-end vary; with some countries reporting values based on RCP8.5 likely ranges, derived from the 2014 IPCC 5th Assessment Report, while other countries already report using much higher SLR scenarios that account for recent insights on the potentially large contributions of the Antarctic ice sheet. The recent IPCC SROCC report (2019) presents higher SLR values than in AR5 and points out that for countries with a low risk tolerance it is beneficial to consider SLR beyond the likely range. According to these new projections a global mean sea level rise of 2m is possible in 2100, but our results indicate that only a few European countries already consider these values, even in an exploratory stage of planning. This suggests that it can take years for countries to update their planning in response to new information. SROCC (IPCC, 2019) pointed out that sea levels will continue to rise beyond 2100, possibly to as much as 5m by 2300. Longer horizons and high sea level values could be used for investments with long lifetimes, such as coastal defenses or city developments (M. Haasnoot et al., 2020), and thus could be very useful for European countries planning. It should be noted that the consideration of higher climate change scenarios does not automatically mean higher SLR values are used in planning. The RCP scenarios 2.6, 4.5 and 8.5 represent the main part of potential SLR projections from the IPCC. Up to 2050, differences in SLR projections are small among these three scenarios, and up to 2100 the differences between RCP2.6 and RCP4.5 are also small.

The science on SLR is rapidly evolving and new insights suggest that SLR could be accelerating and could reach higher levels this century than projected not long ago (Bamber et al., 2018; DeConto and Pollard, 2016). It is critical that these insights and the latest science are considered in SLR planning and implementation. While for some countries the links between science and policy in SLR are well established, we find evidence that improvements can be made for many countries. For example, our results show that in several countries the SLR impact assessments and academic studies are far ahead of government policy or planning documents. Moreover, we noticed that some concepts from SLR research, such as accelerated SLR and mass-loss from Antarctica and Greenland, and planning or decision making under uncertainty are interpreted differently between respondents. Our survey results and communications with respondents also suggest that experts working on SLR are not always aware of existing policies and plans in their country. This often included respondents from governments. In some cases, this may be because SLR is mainstreamed into various policies, but it could also be due to the science-policy interface. Strengthening this link should be a priority to ensure evidence-informed decision making and ensure timely and appropriate responses to SLR. Additionally, institutional capacity building in the area of SLR planning may be needed at different levels of decision-making. This relates to the interaction of policies and decision-makers across governance scales (vertical) and sectors (horizontal) (Storbjörk and Hedrén, 2011).

Our study has collected and analyzed experts' understanding of how European countries are planning for SLR. Despite the novel insights discussed above, critical questions remain. For example, while our study has focused on the policies in place and approaches used to plan for SLR, we did not collect information on their implementation. Understanding if and how policies are implemented in practice - and the challenges and lessons learned in doing so - is critical to assess the current state of preparedness for SLR in Europe. Evaluating whether the measures in place are aligned with the observed and projected impacts of SLR is important (Berrang-Ford et al., 2019). Our understanding of adaptation in coastal areas is limited, with several anecdotal, small-n case studies that focus on best practices. Although insightful, these limit our ability to upscale the findings and make a comprehensive and systematic assessment of implemented adaptation measures globally. With 60% of experts in our survey reporting that they feel their country is preparing reasonably to very well and 28% considering their country not well prepared, further investigation into the actual level of preparedness is an important next step. Given the long lead time required to implement many measures, understanding the current state of preparedness is critical to ensure timely implementation of additional measures where needed.

This **study focuses on European countries**, but clearly many other countries across the globe are also highly vulnerable to SLR. Understanding how and for how much SLR countries are preparing would provide important contributions to the global picture of SLR response. A comparative study could inform what works where and why, which are critical questions for policy orientated learning and support helping the most vulnerable countries (Tamura et al., 2019). To date, however, such a global assessment of progress on planning for SLR is lacking. We can, nevertheless, look to countries where information on SLR planning is available and recognize similarities in the variation of planning responses we found in Europe.

New Zealand, for instance, has national guidance for SLR planning and the country's Coastal Policy Statement stipulates a 100-year planning horizon. The SLR planning guidance explicitly addresses uncertainty, lays out an adaptive planning approach and details four climate change scenarios and associate sea level rise values, based on RCP2.6, 4.5, 6.0 and 8.5 to the year 2150 (Lawrence et al., 2018). The upper bounds of SLR values are 1m by 2100 and 2.5m by 2200, based on RCP8.5 (New Zealand Ministry for the Environment, 2017).

By contrast, in **Australia** adaptation planning and policy-making occurs at the state and local government scale. While SLR is the predominant marine climate change hazard considered in local plans and policies (Bradley et al., 2015), state and local plans vary widely in the presence of SLR in planning, and the values and time horizons used (Bradley et al., 2015; Dedekorkut-howes, Torabi and Howes, 2020). As examples at the state-scale New South Wales has no benchmark or planning horizon for SLR, while South Australia considers 0.3m by 2050 and 1m by 2100, and Tasmania uses a range of 0.4–0.9 for a single horizon of 2090 (Dedekorkut-howes et al., 2020). At the local level, a study of 67 local council policy documents for coastal communities found 42% had no planning document related marine adaptation (including SLR). Whether time horizons and SLR values are defined, and what values are used, varies (Bradley et al., 2015). The isolated actions of individual councils and states have led to spillover impacts between districts (Bradley et al., 2015; Dedekorkut-howes et al., 2020).

In the **United States of America** the National Oceanic and Atmospheric Administration climate adaptation guidance for coastal planners (NOAA Office of Ocean and Coastal Resource Management, 2010), however, states ultimately manage their coastlines and these policies vary (Fu, 2020), similar to Australia and Federalist countries in Europe, like Germany. Some US states take a proactive approach to planning, with guidelines that include multiple SLR scenarios and planning horizons, and guidance for planning under uncertainty. California, for instance considers 82 cm by 2050, 3m by 2100 and 6.7m by 2150 in their highest scenario (California Natural Resources Agency & California Ocean Protection Council, 2018). Some states, such as Virginia and Florida, have laws that mandate SLR inclusion in master plans or projects. However, planning for SLR remains a largely local endeavor (Fu, 2020). Literature from the US sheds light on how this planning and even implementation is being carried out there (Butler et al., 2016; Fu, 2020). Such studies of Europe are needed.

Finally, the small island state of **Kiribati** has national-level planning for SLR which addresses uncertainty and multiple planning horizons and SLR values (Donner and Webber, 2014). In Kiribati, time horizons are based in cultural ‘generation’ terms of grandchildren (to 2036), great-grandchildren (to 2050) and great-great-grandchildren (to 2084). Ranges of SLR values are given per horizon, for instance 6–26 cm by 2050 and a maximum of 85 cm by 2100 (Donner and Webber, 2014).

This small sample of non-European countries appears to reflect our own results in the variation in how and to what extent countries are planning for SLR. Europe could see spillover impacts across borders, similar to those experienced in Australia and the US, if there remain significant differences in the levels to which individual countries adapt. Greater coordination within Europe and globally is needed to ensure timely preparation and to benefit from knowledge and learning exchange between countries. It is important to note, however, that SLR may not yet be on the national agenda of many countries. Vulnerable countries already exposed to a range of climatic and non-climatic hazards often have limited capacity to adapt to long-term issues like SLR. In these countries, response and recovery to natural disasters will or may already be dominating local resources. In other countries, the high impact of hazards such as typhoons and earthquakes may be prioritized over long-term hazards, like SLR. A global overview of the status of SLR planning would be a valuable first step.

In conclusion, our survey results indicate that most countries in Europe are planning for SLR and that North Sea countries with high vulnerability and a long history of SLR planning are planning for the longest horizons and the highest levels of SLR, including high-end and accelerated SLR. However, there remain a concerning number of countries with no or limited SLR planning in Europe. Given uncertainty in SLR and its impacts beyond 2050, adaptive planning approaches and experience sharing across countries could help Europe prepare for SLR in time.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2020.105512.

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