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Implications of Sea-Level Rise for Continental Portugal

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ABSTRACT

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The Portuguese coastline has a high diversity of coastal types, which will react differently to an accelerated sea-level rise. Estuaries and coastal lagoons will be most affected by a rising sea level. Amongst these, the Sado and Tagus estuaries and the Ria de Aveiro and the Ria Formosa coastal lagoons are probably the ones where socioeconomic impacts resulting from accelerated sea-level rise would be greatest. Sandy shores will face increased erosion. However, it is likely that at this type of coast other factors, such as sand deficiency caused by damming river basins, will continue to play a larger role in erosion than accelerated sea-level rise. Hard rocky coasts will be the least affected by accelerated sea-level rise. Specific adaptation policies for accelerated sea-level rise impacts do not presently exist in Portugal. However, existing laws can be used to prevent and/or reduce socioeconomic impacts if they are strictly applied. A strong commitment to coastal management by Portuguese authorities is therefore necessary in order to prevent and minimise future implications of accelerated sea-level rise.

ADDITIONAL INDEX WORDS: *Coastal impacts, coastal erosion, coastal management.*

INTRODUCTION

This paper considers the implications of accelerated sea-level rise (ASLR) for continental Portugal, and consequently excludes Portuguese archipelagos such as the Azores and Madeira. A systematic study of ASLR and, to some extent, its potential consequences started in Portugal in the late 1980s to early 1990s (Dias and Taborda, 1988, 1992; Ferreira, Dias, and Taborda, 1990; Taborda and Dias, 1989; Teixeira, 1990). However, after this initial work, little further research was conducted on the characterisation and quantification of possible impacts. This paper will analyse recent coastal evolution in Portugal in order to place ASLR in an appropriate context. It will also discuss some of the main consequences of ASLR for different Portuguese coastal geomorphic types, including the definition of relative vulnerability.

The Portuguese coastline is more than 900 km long. It is morphologically diverse; existing geomorphological features include extensive sandy shores backed by dunes, rocky coasts with low and high cliffs, pocket beaches, bays, estuaries, lagoons, and barrier islands amongst others. Along the west and south coasts of Portugal, a variety of physiographic alternations can be observed, particularly between rocky coasts and sandy shores. A simple classification of Portuguese coastal types comprising three main types (sandy shores, cliffed coasts, and low-lying rocky shores) is shown in Figure 1. The cliffed coast is the dominant type (*circa* 50% of the Portuguese coast) while low-lying rocky shore is least represented. Also shown in Figure 1 are the main Portuguese rivers with associated estuaries and coastal lagoons. The most important of the coastal lagoons are the Ria de Aveiro (northwest coast of Portugal) and the Ria Formosa barrier island system (Algarve, southern Portugal). The main estuaries are associated with the Tagus and Sado Rivers and are located on the central part of the western Portuguese coast.

The Portuguese coastal zone is highly populated. Most larger cities (*i.e.,* Lisbon, Porto, Setúbal, Aveiro, Faro, etc.) are located near estuaries and lagoons. The morphological characteristics of the coastal area combined with a mild climate have transformed the Portuguese coast into a major international tourist destination since the 1960s. As a consequence, important tourist villages and resorts are also located close to the coastline: about 60% of the Portuguese population live near or in the coastal zone. During the summer, around 80% of the permanent and temporary population (*i.e.,* Portuguese and tourists) are found within a narrow strip along the Portuguese coastline. A large fraction of the Portuguese economy is, therefore, situated near or at the coastal zone. Changes resulting from ASLR can have a direct impact on the economy, either on traditional activities (*e.g.,* shellfish farming, fisheries) or recent ones (*e.g.,* aquaculture, tourism). As a consequence, coastal studies and integrated coastal management are of critical importance in Portugal, including the definition of potential ASLR impacts and adaptation actions.

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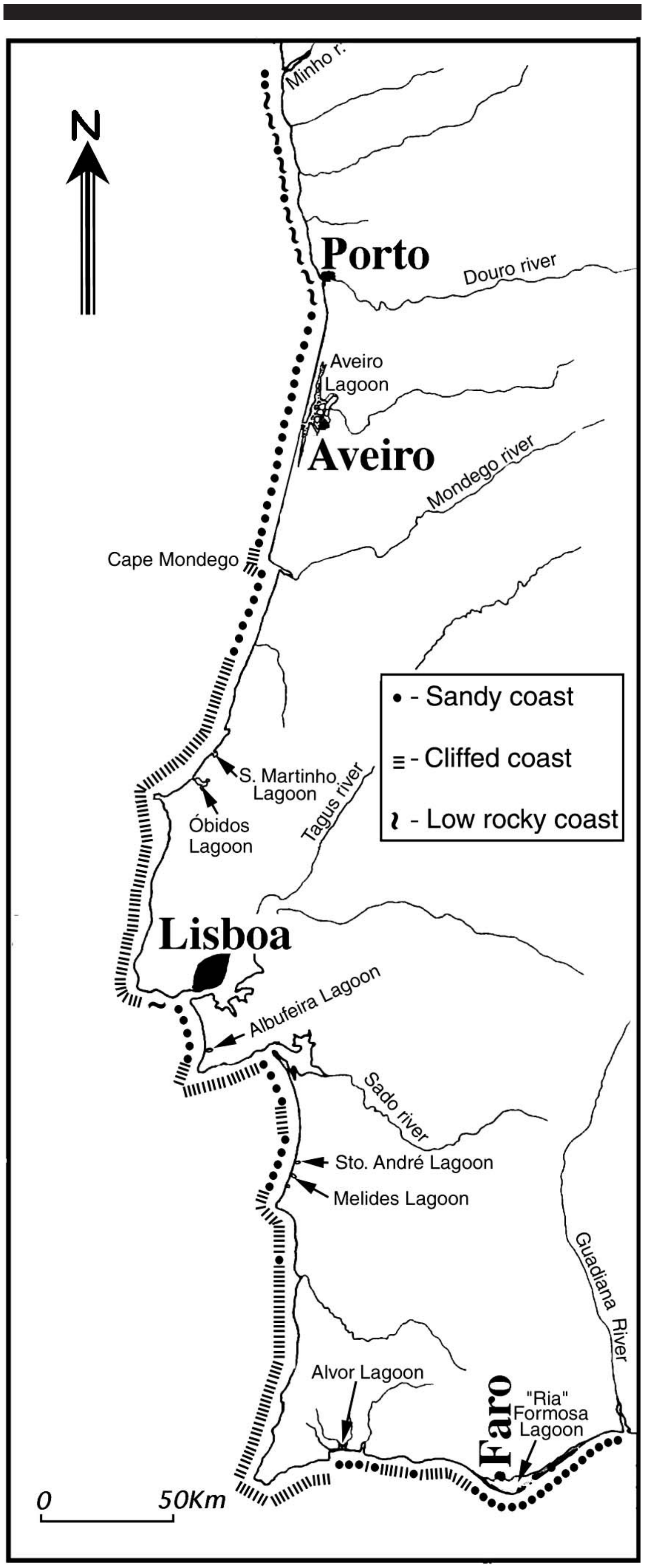

Figure 1. Location map, including main rivers, coastal lagoons, and different coastal types.

CLIMATIC CHARACTERISATION AND VARIABILITY

The effects of long-term coastal change should not be analysed only as the response to ASLR but in a wider context including other aspects of coastal climatology. In fact, climate change will not only affect relative sea level but also the characteristics of storms (strength, duration, frequency), temperature, rainfall, and evaporation rates, among other climate factors. Changes in these factors will also have a major influence on long-term coastal evolution. It is therefore necessary to define present climate conditions, their past evolution, and expected climate changes to develop a comprehensive understanding of their effects on coastal areas.

Temperature and Precipitation

Portugal is located between the latitudes of 37°N and 42°N, in proximity to an important boundary in atmospheric circulation. In the summer, the influence of air masses related to the subtropical Azores anticyclone produces dry and stable weather. During the winter, the influence of air masses related with the frontal systems of midlatitude depressions produces rainy and unstable weather. Geographically, the Portuguese weather can be divided into two main types: the Atlantic, characteristic of the northwestern part, and the Mediterranean, typical of the southern part (Ribiero, Lautensach, and Daveau, 1988).

During the twentieth century, the mean air temperature in Portugal showed a linear increase (Antunes, 1998). Disregarding the impact induced by the urban heat island effect, mean air temperature has risen 0.74°C in one century (Antunes, 1998). This is similar to the global temperature trend computed by Peterson *et al.* (1999) and to the mean annual temperature rise recorded in Europe during the twentieth century, *i.e.,* 0.8°C (Parry, 2000). As a consequence, sea surface temperatures have also warmed several tenths of a degree Celsius in Europe (Parry, 2000).

The mean annual rainfall in Portugal is around 1000 mm, ranging from about 2000 mm in the northwestern hydrographic basins to less than 500 mm in the southern inland ones (Daveau, 1977). The general pattern of future change across southern Europe is for little change or a small decrease in annual precipitation at a possible maximum rate of −1%/decade (Parry, 2000). Another expected climate change is the increase of seasonal variation in precipitation. Southern European winters will get wetter while summers will become dryer. This will lead to a possible decrease in annual stream flow at river mouths in Portugal. Water resources and storage are already a major problem in the Iberian Peninsula with climate change making the situation worse. Since the 1940s, many dams and water reservoirs have been constructed, and, at the end of the 1980s, only 15% of the Portuguese river basins were directly draining to the sea without dam effects (Dias, 1990). Dam construction continues, namely with the construction of the Alqueva dam (on the Guadiana river), which is expected to create Europe's largest artificial freshwater reservoir. The strong gradient in rainfall between the northern and southern part of the Iberian Peninsula has encouraged the development of water bypass mechanisms, widely used in Spain and beginning to be used in Portugal. This water transference is expected to increase in the near future and will probably increase inland flow in the southern rivers of Iberia. However, water retention at dams and its consequent use will further reduce the already limited freshwater and sediment flows at both northern and southern Iberian river mouths. These actions will have a dramatic effect on the natural flood/drought cycle of rivers, leading to a decrease in the sediment transport from rivers and estuaries to the coastal zone and increasing the ability of estuaries to act as a sink for marine sediments. The overall decrease of sediment supply to the littoral and shelf systems will enhance coastal erosion.

Wave Regime

On the west coast, the wave regime is dominated by swells from the northwest that occur 73% of the year, with a mean annual significant wave height of 2.2 m and annual average peak period of 11.3 s at Figueira da Foz (Costa, C.L., 1994). The dominant association between significant wave heights, peak periods, and wave direction is: wave heights of 1 to 3 m, periods of 9 to 13 s, and northwest wave directions, accounting for 50% of occurrences. Storms are a frequent phenomenon, often inducing dramatic consequences. On the west coast, the most frequent storms are from west-northwest. A considerable number of storms (between 3% and 17%) have significant wave heights exceeding 10 m (Pita and Santos, 1989).

The south coast is not exposed to the swell generated in the North Atlantic. Consequently, wave conditions are less severe, with dominant significant wave heights between 0.6 and 1.5 m and peak periods between 6 and 11 s (Costa, M., 1994). The most frequent storms on the south coast are from the southwest with significant wave heights generally smaller than 5 m but occasionally exceeding this value (Costa, M., 1994).

An analysis of 127 years of wave regime data and information from newspapers by Andrade *et al.* (1996) suggests an increase in storminess on the Portuguese coast. However, the high decadal variability in storminess and the poor data quality until the middle of the twentieth century did not allow the above authors to be conclusive on this subject.

North Atlantic Oscillation

The North Atlantic Oscillation (NAO) is the meridional contrast between sea-level pressures at the Azores and Iceland (Hurrell, 1995). It is the dominant mode of winter climate variability in the North Atlantic region, including changes in circulation patterns, high/low atmospheric pressure systems, and variations in temperature and precipitation. For example, the NAO has been related to evaporation and precipitation (Hurrell, 1995) and the climate circulation mode of the western Mediterranean (Vignudelli *et al.*, 1999). In Portugal, the NAO has been successfully related to short-term oscillations in mean sea level (Guerra, Pires, and Taborda, 2000), but it does not explain the increasing sea-level rise trend (see the following section). The above mentioned works highlight the potential of the NAO to act as a link between several climatic and oceanographic factors that have a major influence on coastal evolution, but they also show that further studies are need to fully understand their relationships.

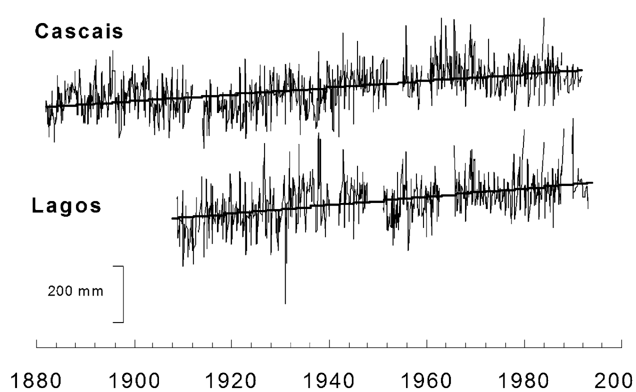

Figure 2. Monthly mean sea level data at Cascais and Lagos tide-gauge stations. Superimposed are the linear least-squares best-fit lines.

SEA-LEVEL RISE CHARACTERISATION

The analysis of coastal tide-gauge records has provided the main method by which sea level has been measured during the twentieth century. In Portugal, there are several coastal and island tide gauges that monitor sea level. However, most of these stations have a relatively short record (<50 y), which is unsuitable for long-term mean sea-level trend determination (Douglas, 1991). A linear regression of the longer tide-gauge records of Cascais and Lagos (Figure 2), of 104 and 78 years duration, respectively, revealed rising trends of 1.3 ± 0.1 and 1.5 ± 0.2 mm/y, respectively (Dias and Taborda, 1992). These results clearly indicate a significant rise of relative sea level in Portugal during the twentieth century; this rise is within the range of most global estimates (*e.g.,* Barnett, 1984; Douglas, 1991). The temporal structure of the Cascais tide-gauge data suggests that relative sea level has not risen consistently. From the end of the nineteenth century until 1920, mean sea level dropped at a mean rate of 0.5 ± 0.4 mm/y. Subsequently, relative sea level has shown a net upward trend of 1.7 ± 0.2 mm/y.

Dias and Taborda (1988) predicted a sea-level rise for Portugal between 14 and 57 cm by the year 2100, according to different scenarios. This range is smaller than the 13- to 68-cm rise predicted by Parry (2000) for the global mean sea-level elevation by the 2050s. However, the values for Portugal are based on the extrapolation of simple fits to the observed data, while the global values are based on a series of different sea-level rise scenarios as a function of different temperature changes.

IMPACT AND VULNERABILITY TO SEA-LEVEL RISE

Recent Coastal Evolution in Portugal

At present, the Portuguese coastal zone is strongly affected by coastal erosion caused by a significant sediment deficiency, which started at the beginning of the twentieth century, and increased significantly after the 1940s. This lack of sediment is mainly due to human intervention in river basins, particularly dam construction (*e.g.,* decrease of flood frequency and magnitude), sand and gravel mining, and extensive estuarine dredging for navigation. These actions have significant consequences on open sandy shore coastal stretches. Furthermore, the restricted sediment supply is often exacerbated downdrift of harbour jetties, breakwaters, and hard protection structures. Currently, shoreline retreat rates of >1m/y affect more than 50% of the Portuguese sandy shores, with the maximum recession rate being >10 m/y south of Espinho, between 1980 and 1989 (FERREIRA and DIAS, 1991). In contrast, estuarine areas are being infilled due to natural and human causes. Hard rocky shores (cliffed and noncliffed) have been less affected by changes in sediment availability because these coastal sectors already have a sediment deficiency.

Impacts on Estuaries and Coastal Lagoons

The main impact of ASLR on wetlands and coastal lowlands will be inundation and a natural trend for upward and landward displacement of these ecosystems. If allowed, this displacement should not result in the destruction of the coastal system or the associated economic resources. However, because extensive lowland areas are occupied by fixed man-made structures, the landward migration of these systems is unlikely to be allowed. As a result, coastal squeeze is observed, and much of the natural, social, and economic value is being degraded and could ultimately be lost. The main coastal lagoon areas in Portugal (Ria de Aveiro and Ria Formosa) are facing erosion of the oceanfront and silting up of tidal channels. Both areas are intensively occupied at their inland limit, including important coastal towns, such as Aveiro (Ria de Aveiro), Faro, Olhão, and Tavira (Ria Formosa). As a consequence, the future evolution of these systems will be toward a reduction of their areas, probably exacerbated by ASLR. The shrinking of these systems will contribute to an increase in the silting up because tidal prisms will be smaller, the induced current velocities will decrease, and deposition rates will be higher.

The small lagoons of the Portuguese coast (*e.g.,* Esmoriz, Óbidos, Albufeira, S. Torpes, Melides, and Alvor) also experienced increased channel infilling during the twentieth century, possibly due to the reduced magnitude of flood events combined with natural trapping of marine sediments. Most of these lagoons are currently kept open by dredging. As with the lagoons, lateral expansion of the landward boundaries of estuaries in response to ASLR is not possible for the main Portuguese estuaries because these limits are artificially defined by harbours and coastal towns. Some of the most important towns of Portugal occur on estuarine margins (*e.g.,* Lisbon at the Tagus estuary, Porto at the Douro estuary, and Setúbal at the Sado estuary). As a consequence, estuarine areas have been decreasing as a result of land claim. In summary, the evolution of coastal lagoons and estuaries during the twentieth century was characterised by erosion on the ocean front, infilling of channels, and a reduction of the lagoon and estuarine areas. The expected evolution for the twenty-first century is a continuation of channel infilling, possible saltmarsh inundation, and further coastal squeeze.

Impacts on Sandy Coasts

Sea-level rise is the main factor causing shoreline retreat in coastal areas under dynamic equilibrium, *i.e.,* where the natural sand supply allows the potential and the effective littoral drift to be equal. However, on sandy shores, where this supply has been strongly reduced (as already discussed), the main cause of shoreline retreat is sediment deficiency.

Retreat rates observed for the 1940s and 1950s at Portuguese sandy shores do not consistently indicate erosion or accretion but point to a dominantly erosive behaviour. In general, shoreline retreat values did not exceed 0.5 m/y, with averages between 0.2 and 0.4 m/y. The observed shoreline evolution rates during the 1940s and 1950s can be considered as indicative of "natural" retreat rates because sand deficiency was not yet significant at that time. Hence, sea-level rise may have been responsible for most of the shoreline evolution observed until the middle of the twentieth century, in general inducing low to moderate retreat rates (FERREIRA, 1993; TEIXEIRA, 1990; ZHANG, DOUGLAS, and LEATHERMAN, 2004).

Presently, erosion is mainly induced by sediment scarcity in coastal systems, being responsible for average shoreline retreat rates on the order of 1 m/y on most of the Portuguese sandy coast. Values computed by applying the Bruun Rule (FERREIRA, 1993; TEIXEIRA, 1990) point to average (sandy) shoreline retreat rates directly caused by sea-level rise on the order of some tens of centimetres per year, which only accounts for 10% to 15% of the actual shoreline retreat. Hence, ASLR can be considered a secondary but nevertheless important cause of shoreline retreat, especially in some particular situations. For example, on sandy beaches backed by cliffs or by seawalls, the beach profile will not be able to migrate landward. Therefore, there will be an increase in water depth, causing a reduction in cross-shore wave energy dissipation and increasing the amount of nearshore wave attack (SÁNCHEZ-ARCILLA *et al.,* 2000), encouraging more erosion. A similar process can occur in places where sand starvation is extreme. This can upset the natural dynamic equilibrium, and the profile will be displaced further inland, including dune degradation. Beach response to ASLR will enhance this process. Because low-lying coastal plains often exist landward of coastal dune ridges, degradation or complete destruction of the dune would expose those inland areas to oceanic processes. In such cases, ASLR will contribute to the increased possibility of extreme coastal flooding and overwashing during storms. On the Portuguese coast, two areas could be directly affected by this situation: the coast in front of Ria de Aveiro, particularly south of the Aveiro harbour jetties, and the coast of Ria Formosa.

Impacts on Rocky and Cliffed Coasts

Cliffs and rocky coasts will not adjust instantaneously to changes in sea level. There will almost certainly be lags in their response (BRAY and HOOKE, 1997). An increase in water depth at the nearshore in front of rocky coasts will occur with ASLR. Existing rocky platforms or low lying outcrops will be submerged more often and energy dissipation prior to wave incidence at the cliff toe will decrease. This effect will be exacerbated during storms. As a result, cliff retreat rates can be expected to increase in the near future. The result will be site-specific because of local factors governing cliff and rocky coast sensitivity to wave erosion. Hard-rock and sheltered coasts will be less influenced by this change, while soft cliffs on exposed coasts will experience accelerated erosion.

The Portuguese rocky coast is composed of many different types of rocks, and they experience a range of wave exposure. This makes it difficult to express a simple relationship between ASLR and impacts at this type of coast. However, some coastal areas will probably face increased erosion in relation to others, specifically, the low-lying rocky coast of Minho (northwestern Portugal), where cliffs are generally not present to act as a buffer to wave attack, and soft-cliffed coasts (about 10% of the Portuguese coast). In other areas with hard rocky coasts (about 450 km for the Portuguese coast), immediate changes induced by ASLR might be negligible. On some cliffed and rocky coasts, there are small sandy beaches in front of the cliff or between outcrops. With a rising sea level, a reduction in the area of these sandy beaches and eventually their total disappearance is to be expected. This trend has already been observed over the last few decades for several sandy beaches adjacent to rocky shores (*e.g.,* southwest coast and western part of the Algarve).

SYNTHESIS OF COASTAL VULNERABILITY TO SEA-LEVEL RISE IN PORTUGAL

The overall analysis of the aforementioned impacts of ASLR on the Portuguese coast enabled the development of a simplified vulnerability map based on the coastal geomorphology, in which vulnerability is classified in three categories: low, medium, and high (Figure 3). The different categories represent a qualitative evaluation of the size of expected impacts. Low-lying areas, estuaries, coastal lagoons, and wetlands in general are considered areas of high vulnerability; sandy shores and low-lying rocky shores are classified as having medium vulnerability; and hard rocky coasts are classified as low vulnerability. The association of high vulnerability to sea-level rise in Figure 3 with significant human occupation is useful in defining areas with a high potential coastal hazard (including socioeconomic consequences). For Portugal, these areas are the most occupied and exploited coastal lagoons (Ria Formosa and Aveiro) and the most populated large estuaries (Tagus and Sado).

Socioeconomic Impacts

Knowledge of the potential socioeconomic impacts of ASLR on the Portuguese shore is still poor. No quantitative studies on direct and indirect economical and social impacts of ASLR on estuaries, saltmarshes, lagoons, etc., have so far been completed for Portugal. Consequently, potential impacts can only be estimated qualitatively. Potential socioeconomic impacts of ASLR were categorised by NICHOLLS and KLEIN (2000) as follows:

- Direct loss of economic, ecological, cultural, and subsis-

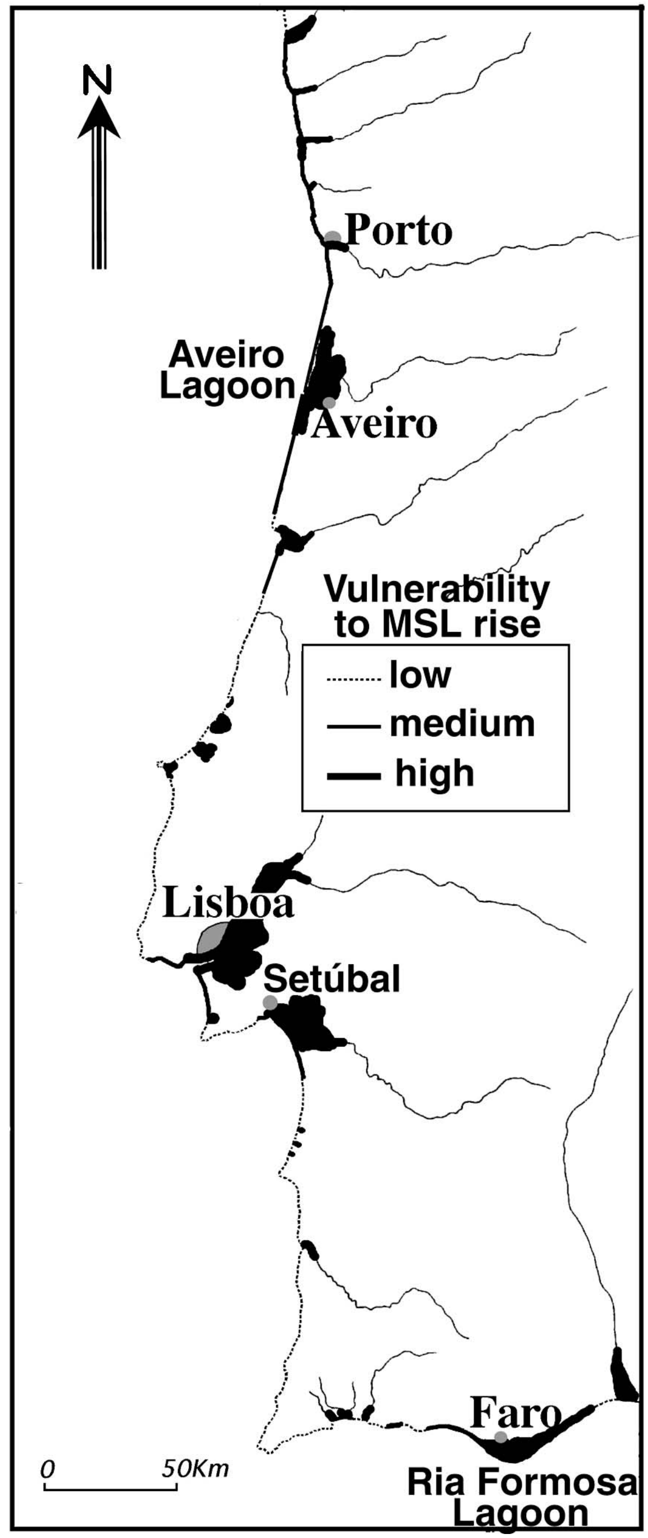

Figure 3. Map of coastal vulnerability to ASLR in Portugal.

tence values through loss of land, infrastructures, and coastal habitats;

- Increased flood risk of people, land, and infrastructures;
- Other impacts related to changes in water management, salinity, and biological activity.

Most of these impacts are relevant to the Portuguese shore, especially for the majority of estuaries, coastal lagoons, and lowlands in general. Site-specific impacts can also be identified. The risk of increasing flood and overwash was mentioned above for two regions (Ria de Aveiro and Ria Formosa), which have a fragile dune ridge as ocean defence and low-lying occupied areas inland. This could affect all economic activities in these areas, including navigation, tourism, recreation, fisheries, and shellfish farming.

The continuation of the silting trend of the channels will lead to the reduction of water exchange and quality in coastal lagoons and to increased difficulties in navigation and harbour exploitation. This situation may be exacerbated by the increase in storm overwashing, inducing onshore transport of marine sands inside the lagoon and estuarine systems. As a result, shellfish farming and aquaculture in Portugal are likely to be strongly influenced by the consequences of ASLR. These activities are important in several Portuguese estuarine and coastal lagoon areas. The same siltation processes will reduce the ability of coastal systems to act as nursery areas, with direct consequences on fisheries. Moreover, navigation channels will be filled up, requiring ongoing maintenance programmes. Probable loss of saltmarshes and other wetlands by erosion or inundation will also directly affect bird nesting and bird migration. Because most of the Portuguese wetlands are recognised and classified according to international ecological conventions such as the RAMSAR Convention, this will result in the loss of important environmental values. Another important socioeconomic impact in Portugal could be reduced tourism because the increase in coastal retreat will cause a reduction or total disappearance of some sandy beaches. This consequence will be more detrimental in areas where the upward and landward profile migration cannot occur (*e.g.,* artificial coastlines and beaches backed by cliffs), leading to coastal squeeze. Coastal areas like the western part of Algarve, the most touristic part of Portugal, could be severely affected if no action is taken because the reduction of the beach area will cause a reduction of the tourist occupation capacity of each beach. The attractiveness of the affected areas will also be reduced by loss of sandy beaches. Moreover, existing tourist-related buildings and facilities adjacent to existing beaches will be further threatened by ASLR and coastal erosion.

MANAGEMENT APPROACHES

Portugal has been a pioneer in the development of laws regarding the protection of the coastal zone, with the introduction of the Public Maritime Domain (Domínio Público Marítimo) at the end of the nineteenth century. The law established that the entire Portuguese coastline could not be turned into private property and permanent settlement could not occur without governmental agreement. As a result, the Portuguese coastline is still a public domain and most coastal areas have been preserved from urbanisation.

However, the pressures continue, and there is currently no major national plan to assess or manage vulnerability to impacts of ASLR. In reality, the hazard is frequently considered small. This is mainly a result of the lack of relevant studies and a restricted public awareness of the potential impacts of ASLR. Coastal managers are not particularly concerned with such hazards because coastal erosion due to sediment starvation and storm action is already a dramatic issue in Portugal and cause direct short-term impacts at least one order of magnitude higher than those currently associated with ASLR. Therefore, there are no current policies on the technical and institutional aspects of adaptation to ASLR in Portugal. Consequently, the present policy perspectives do not include long-term coastal evolution and associated sea-level influence, even though the relative sea level is rising (see Figure 2). However, ASLR impacts could be as important as storm and coastal erosion impacts in some places if considered over the long-term (decades). For instance, storm impacts are discrete and frequently reversible on a human scale (year to decades) if sediment starvation is naturally or artificially reduced (*e.g.,* beach nourishment, dune building). On the contrary, direct and indirect consequences of ASLR can be irreversible or extremely costly if no action is taken in due time. Therefore, adaptation actions must be taken earlier in order to prevent adverse consequences some decades later.

Portugal has relatively recent laws for coastal management, which should be able to minimise ASLR consequences if correctly and strictly applied. The older laws regarding the Public Water Domain (Domínio Público Hídrico) and the new Coastal Zone Management Plans (Planos de Ordenamento da Zona Costeira) define protection margins around the entire Portuguese coast and wetlands between 50 and 500 m wide. The entire coastline, including submerged areas to a depth of 30m, coastal wetlands, and riverine areas, are also integrated in the National Ecological Reserve law (Reserva Ecológica Nacional). These laws restrict occupation and try to preserve natural and ecological values by defining rules for their use. Furthermore, a large part of the Portuguese coast belongs to Natural Parks and Reserves (Ministry of Environment) and is thus under the protection of specific natural protection laws. Collectively, these laws should minimise socioeconomic impacts resulting from ASLR by minimising or even stopping coastal urbanisation. However, tension exists between the goals of local authorities (*e.g.,* councils) and central authorities (*e.g.,* Ministry of Environment), and despite these laws, coastal urbanisation is still increasing. This is most obvious in tourist areas, such as the Algarve coast. Settlements in close proximity to the coastline are allowed by (i) profiting from the exceptions considered in those laws, (ii) exerting the possibility of occupation if defined and approved prior to the existence of the recent laws, and (iii) showing total disrespect of the law. Because the Portuguese judicial system normally takes several years to solve situations such as illegal construction, the law becomes ineffective. As a consequence, development of any future policy or modification of existing laws to face ASLR impacts must include a careful and effective control programme and a strong political will to enforce the law. Simultaneously, a hard and long-term commitment has to be made in order to increase the awareness of coastal managers and the general public to the possible impacts of ASLR and the associated direct and indirect social and economic impacts. Changes related to ASLR often occur slowly and may be almost imperceptible at the short-term political cycle. However, addressing this issue is urgent because actions to solve the problem will be increasingly costly if coastal urbanisation continues.

CONCLUSIONS

Potential implications of ASLR for Portugal are not expected to be as dramatic as in some low-lying countries around the world (*e.g.,* Bangladesh, Maldives, or the Netherlands). Furthermore, it is also difficult to dissociate the consequences of ASLR from other coastal impacts resulting from human actions (*e.g.,* coastal erosion due to sediment deficiency). In Portugal, these impacts are normally greater by about one order of magnitude than the ones caused by *present* rates of sea-level rise. This trend will probably not change in the near future. Consequently, the evolution of the Portuguese coast will be mainly dependent on the direct result of human actions. ASLR can be considered as a secondary but important cause of coastal change. The Portuguese areas that will probably be most affected by ASLR are the coastal lagoons of Ria Formosa and Ria de Aveiro, and the Tagus and Sado estuaries. For these wetlands, as in others of the Portuguese coast, possible consequences of ASLR include increased channel silting, a higher degree of marine action, an increase in the influx of marine sediments, and a decrease of their global areas, leading to coastal squeeze. The main impacts on sandy shores will be an increase in shoreline retreat rates and a decrease of sandy beach areas, especially where backed by fixed artificial structures or cliffs. Low-lying rocky shores will probably experience a decline or complete loss of existing pocket beaches, while cliffed areas will be subjected to higher wave energy levels. However, these coastal regions will be the ones facing smaller impacts induced by ASLR. All the above consequences of ASLR will induce diverse socioeconomic impacts, with the most affected areas being navigation, tourism, and traditional activities, such as shellfish farming.

The common practice to minimise coastal erosion problems has been to combat the shoreline retreat by using hard protection structures (groynes, seawalls, etc.) or, more recently, beach nourishment. Because there is no general policy about how to face ASLR consequences in Portugal, a future use of local and punctual remediation or rectification policies rather than the use of a global approach can be expected. This will result in possible increase of ASLR impacts in some areas and in a long-term augmentation of general expenses to diminish coastal hazards. A correct use and application of existing Portuguese laws, such as the Public Water and Maritime Domains, could be helpful in avoiding or reducing the potential socioeconomic impacts. However, coastal management practice during the last decades frequently disrespected the basic concepts of such laws, leading to an aggravation of coastal hazards and an increase in vulnerability. It is therefore necessary to implement a new coastal management concept and approach, including a national plan of adaptation to ASLR impacts in the wider context of coastal management and to increase the public awareness to such problems.

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□ RESUMO □

A zona litoral de Portugal Continental possui uma elevada diversidade de tipos de costa, reagindo de forma distinta à subida relativa do nível médio do mar. Os estuários e as zonas lagunares serão as áreas potencialmente mais afectadas por essa subida. De entre estas áreas, os estuários do Tejo e do Sado e as zonas lagunares correspondentes à Ria de Aveiro e à Ria Formosa serão, provavelmente, aquelas onde maiores impactos socio-económicos se poderão esperar. As praias arenosas estarão sujeitas a um incremento na erosão costeira. Contudo, neste tipo de costa, a deficiência no abastecimento sedimentar deverá continuar a ser o principal indutor de erosão costeira. As zonas costeiras rochosas serão as menos afectadas pela subida relativa do nível médio do mar. Não existem, actualmente, em Portugal, medidas específicas de actuação tendentes à minimização dos impactos associados a uma subida do nível do mar. No entanto, as leis existentes podem ser usadas na prevenção e/ou redução de impactos socio-económicos, desde que se cumpra de forma estrita a sua aplicação. A prevenção de futuros impactos resultantes de uma subida relativa do nível médio do mar obrigará à existência de um elevado empenho, no futuro próximo, por parte dos gestores costeiros em Portugal, com vista à criação de planos de gestão costeira integrada.