Climate change impact on the built environment in coastal regions

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1 Introduction

Out of all EU countries, Sweden boasts the longest coastline (SMHI, 27 May 2020). The Swedish coastline stretches from Haparanda in the north to Strömstad in the west, reaching approximately 7,600 kilometres from end to end[1] (Boverket, January 2006, p 23). Taking into account the many islands, islets, rocks and piers that exist along the Swedish coastline as well as some shorelines along larger rivers that number increases significantly: in a project mapping Swedish shorelines from 2005-2020, the Swedish Mapping, Cadastral and Land Registration Authority in collaboration with the Swedish Maritime Administration covered an impressive 48,000 kilometres of shoreline (Lantmäteriet, n.y.). This number illustrates how much of Sweden borders waters, and the importance that both the sea and inland rivers play to the country. This both has implications and creates unique opportunities for the Swedish environment, economy, and society.

To a large extent, the Swedish coastline is surrounded by the Baltic Sea, a sea whose unique properties stipulates the living conditions on the coast, both on land and in water. The Swedish Baltic Sea coastline extends all the way from the northernmost parts of the Bothnian Bay on the eastern coast to Skagerrak in the west (Baltic Marine Environment Protection Commission, n.y.). Its water is brackish - i.e., neither truly fresh nor truly salty but something in between –, a quality which contributes to Sweden's unique marine and coastal environment, flora, and fauna.

[1] Taking into account larger bays and the coastline of some of the greater islands.

2 Background

Swedish coastal areas

Sweden is an oblong country, stretching over 1,500 kilometres from its northernmost to its southernmost point. This means that climate and weather naturally vary a lot across the country, and the same is true for the conditions along the coastline.

In popular speech, the Swedish coastline is divided into three parts – the eastern, southern, and western coasts –, with each of these parts in turn being divided into smaller zones or strips. In the north, Norrlandskusten ("the coast of Norrland"; Norrland is the northernmost part of Sweden) stretches from Haparanda in the north to Gävle in the south, covering four counties and 17 municipalities along the way (Höga Kusten, n.y.). This part is the longest of the Swedish coastal areas. Its northernmost parts are characterized by beautiful nature, a stunning archipelago and the many great rivers which enter into the sea here, and which greatly impact the eco-system and biodiversity in this area. A little further down south, Höga Kusten ("the High Coast") is located, a strip of coastline which has been designated a world heritage site by UNESCO because of how much the Earth's crust is rising there (Kramfors Kommun, 7 January 2021), and which is also known to the Swedes for its beauty. This area is known for its many types of rocks and their varying sensitivity to erosion, wind, and climate. These differences have rendered great variations in height along the coastline, resulting in a sensational nature for those seeking beauty, and interesting conditions from a geological standpoint.

As a general rule, the further down south along Norrlandskusten you go, the more populated and industrialized the landscape becomes. A majority of Norrland's population lives along the coast, and many important cities such as Luleå, Piteå, Skellefteå, Umeå, Önsköldsvik and Sundsvall are located there. Important infrastructure such as several railways and European route E4 connect these cities.

South of Norrlandskusten the most abundant archipelago in the Baltic Sea is situated, Stockholm archipelago. Encompassing close to 30,000 islands, islets, and rocks (Stockholm Archipelago, n.y.) this archipelago is located just outside of the Swedish capital, an area which hosts almost three million people (Statistiska Centralbyrån, 12 May 2021). Stretching from Öregrund in the north to Landsort in the south this archipelago rugged nature, wooded islands, rocky cliffs, and sandy beaches are found side by side here. Due to being located right outside the Swedish capital, this area is also rich in infrastructure and commerce, and 200 out of the 30,000 islands are also inhabited (Länsstyrelsen Stockholm, 2017), with around 10 000 Swedes living in the archipelago year-round (Skärgårdsstiftelsen, n.y.). This means that boats, ferries, and ships carrying cargo criss cross their way through the archipelago on a daily basis, and that important built environment elements such as schools, gas stations and grocery stores have popped up around the islands.

Southeast of Stockholm, Sweden's two largest islands, Gotland and Öland, are situated. Gotland is Sweden's largest island, hosting around 60,000 inhabitants on its 3,135 km^2 (Regionfakta, n.y. a). This island is highly interesting both because of its nature and because of its history – around 70% of the island has been deemed worthy of protection by the government because of its cultural, historical, and environmental value, while 27% of its surface is currently protected (Regionfakta, n.y. b). 42,000 ancient monuments make the island interesting from a built environment perspective, and barren limestone has provided the conditions needed for a unique flora and fauna, with some species to be found on this island only (Visby Handelstorg, n.y.). This is true also of Öland, which similarly to Gotland boasts a unique nature and many ancient monuments, and which hosts the world heritage site Södra

Ölands Odlingslandskap. Despite being the smallest county in Sweden with a mere 24,600 inhabitants on its 1,344 km^2, this island is home to 85 nature reserves, telling of the unique nature and climate that can be found there (Ölands Turistbyrå, n.y.). It is also a highly attractive destination for Swedes during the summer, which means that large parts of the island are covered by summer houses and the temporary built environment elements needed to support a summer population more than ten times its original population (Ölands Turism, n.y.).

Norrlandskusten, Stockholm archipelago, Gotland and Öland are all part of the eastern coast of Sweden. Along its southern part, we find Blekinge archipelago, the coasts of Skåne, and Öresund, the straits that separates Sweden from Denmark. Just as Stockholm archipelago, Blekinge archipelago is ripe with islands, islets, and rocks of various sizes, which, in combination with the brackish water there, has contributed to unique eco-systems and a rich biodiversity. Characteristic for this coastal area is the prevalence of oak, beech, and other types of deciduous trees, in stark contrast with the northern parts of Sweden where pine and fir prevail (Blekinge Arkipelag, n.y.). Much work is therefore done to protect and preserve the nature there. In addition, this area is highly populated with many of Blekinge's bigger cities located right by the sea, and therefore infrastructure in terms of boats and ferries exists in the archipelago.

Also the coasts of Skåne and Öresund are highly populated, with Malmö, the third largest city in Sweden, being located in Öresund, and the Danish capital being located just across the water. Skåne is surrounded by the sea on three sides, which means that the proximity to the sea to a large extent affects life there. Its eastern and southern coastline are sandy beaches, whereas most of the western coast along Öresund consists of cliffs and moraine beaches (Länsstyrelsen Skåne, n.y.). With regards to infrastructure, three of Sweden's biggest industrial ports are situated along the coast of Skåne, in Helsingborg, Malmö and Trelleborg (Länsstyrelsen Skåne, n.y.). Naturally, a lot of infrastructure and communication has popped up both to support these important ports and to support commuting workers and commerce between Sweden and Denmark.

After Öresund, the Baltic Sea opens up into the Atlantic. This means that waters become saltier and the conditions in water and on land change. The western coast of Sweden therefore differs from the eastern and southern parts in terms of climate, weather, flora and fauna. As it borders the Atlantic, its ecosystems are not affected by brackish water and changing salinity levels to the same extent as the coastlines bordering the Baltic Sea.

The western coast because of its nature and weather is a highly popular tourist attraction among the Swedes. To illustrate, Bohuslän county, which is Sweden's westernmost county, boasts 3,000 islands and 4,500 islets in its archipelago, an archipelago which is characterized by a special type of rock to be found only here - bohusgranit (Nationalencyklopedin, n.y.). This rock has via erosion and large ice melting been shaped into smooth, sculptural shapes. Both flora and fauna are rich in species there compared to the rest of Sweden, both in the sea where the salty Atlantic water supports a greater variety of species than in the Baltic Sea, and on land. Along the western coast, Sweden's second largest city, Gothenburg, is situated. The city itself is home to close to 600,000 Swedes, with many more living in the areas around it (SCB, 31 December 2020).

The Baltic Sea

The Baltic Sea surrounds most of the Swedish coastline, except for the western coast which borders the Atlantic. Much of the conditions along the Swedish coastline are therefore dependent on what

happens in the Baltic Sea, and vice versa. Coastal and marine ecosystems are largely intertwined, and activities on land may affect conditions in the water just as much as activities in the sea may affect life along the coast. While water levels and flows in great rivers as well as eutrophication of Swedish farmlands are among factors on land affecting water, blooming of algae, and changing natural habitats of certain fish are among factors in the sea affecting life on land.

The Baltic Sea is divided into several regions, stretching from north to south: The Gulf of Bothnia, the Gulf of Finland, and the Baltic Proper. These regions are in turn divided into several sub-regions: The Gulf of Bothnia comprises the Bothnian Bay, the Bothnian Sea, the northern Sea of Åland and the northern Archipelago Sea; and the Baltic Proper consists of the Northern Baltic, the Central Baltic, the Southern Baltic, and the Gulf of Gdansk (Skansen, n.y.). The Swedish coastline borders the Bothnian Bay, the Bothnian Sea, the Northern Baltic Proper, and the Southern Baltic Proper within the Baltic Sea itself, as well as Skagerrak and Kattegatt in the west (Sveriges Vattenmiljö, n.y.a). Each of these regions has its unique conditions, conditions which are decided by ever-varying salinity levels in the water (Sveriges Vattenmiljö, n.y. b):

- **The Bothnian Bay and the Bothnian Sea:** The coastal area around the Bothnian Bay and the Bothnian Sea is characterized by its many large rivers which have their outflow into the sea. This means that up to 80% of the water in the sea there is fresh and that salinity is very low (Havet.nu, 8 April 2021). Its eco-system therefore contains a mixture of freshwater and saltwater species (both flora and fauna), as well as a rarity of species specialized for brackish water. Among the freshwater species we find roach, perch, pike, and grayling, and among saltwater species are herring, sprat and sandeel. These waters are also characterized by the fact that they are covered by ice four to six months a year, an ice which is of great importance to life and biodiversity there and which for instance supports various types of seal.
- **The Northern and Southern Baltic Proper:** These waters are truly brackish, i.e., with conditions that are neither salty nor fresh but a mixture (havet.nu, 11 May 2021). Very few species therefore enjoy living there, and for many species these waters present the northern frontier of their natural habitats. The water there is also permanently stratified as surface and deep waters differ in salinity and do not mix, which means that some of the deeper waters are oxygen deprived and provide harsh conditions for life. Despite these dire open water conditions, the Baltic Proper actually provides varied and rich conditions for life around the coastline – waters there are shallow and sunlit, which means that many species thrive there. The coastline around these waters provides many different types of environments, such as archipelagos, long beaches, shallow coves as well as clean rocks, providing both protective environment and a variety to support many different species.
- **Skagerrak and Kattegat:** Situated along the western coast, these are Sweden's saltiest waters, and also the richest in species (havet.nu, 19 April 2021). Many types of fish, crabs, mussels, starfish, anemones, seals, and whales are found there. The salt level in Skagerrak is higher than in Kattegatt which functions as an entrance to the brackish Baltic Sea, and is therefore also richer in species. Around 130 species of fish along several hundred different algae and several thousand animal species have been found along the coast of Bohuslän county, and it also hosts the only coral reef in Sweden (Sveriges Vattenmiljö, n.y. c).

Built environment along the Swedish coast

In addition to supporting a variety of ecosystems and species, the Swedish coastline is highly built up, and is also highly populated in proportion to the rest of the country. Sweden's three largest cities (Stockholm, Gothenburg and Malmö) are all located right by the sea, representing close to two million people alone (Statistiska Centralbyrån, 31 December 2021).

Statistics Sweden summarizes the extent to which the built environment affects Swedish coast- and shorelines in this way (Statistiska Centralbyrån, 19 October 2011, p 1):

- 40% of the Swedish coast, including some of the larger islands, accommodates buildings within 100 meters from the shoreline
- 74% of the Swedish coast, including some of the larger islands, accommodates buildings within 300 meters from the shoreline
- Out of around 7,2 million buildings in Sweden as of 2010[2], 14% are located within 100 meters from the coast- or shoreline. The proportion of buildings located within 100 meters from the coastline varies around the country, from 27% in Norrbotten county in the north, to 6% in Gotland county in the southeast
- The average building density along the coast is 1.4 buildings per hectare. Also this number varies within the country, from 2.6 buildings per hectare in Skåne county to 0.6 buildings per hectare in Gotland county
- The greatest proportion of coastline affected by buildings is found in Stockholm, whereas the greatest density of buildings is found in Skåne county.

As shown by the above numbers, not much of the Swedish coastline remains unaffected by humans or the built environment. Table 1 below further details how much of the Swedish coastline accommodates buildings, covering the counties along the mainland coast as well as Gotland (Statistiska Centralbyrån, 19 October 2011, p 7):

County code	County	Share of coastline accommodating buildings	
		Within 100 meters	*Within 300 meters*
01	Stockholm county	53 %	84 %
03	Uppsala county	28 %	58 %
04	Södermanlands county	40 %	74 %
05	Östergötlands county	29 %	61 %
08	Kalmar county	31 %	66 %
09	Gotland	22 %	61 %
10	Blekinge county	41 %	78 %
12	Skåne county	40 %	75 %
13	Hallands county	28 %	75 %
14	Västra Götalands county	44 %	84 %
21	Gävleborgs county	46 %	74 %
22	Västernorrlands county	44 %	73 %
24	Västerbottens county	48 %	80 %
25	Norrbottens county	43 %	77 %
00	**Total**	**40 %**	**74 %**

Table 1. Percentage of the Swedish coastline accommodating built environment.

[2] This includes all buildings registered by the Swedish Mapping, Cadastral and Land Registration Authority.

Although there are great variations across the country, it remains clear that much of the coastline is affected. Stockholm county is the most built, which is due to the fact that the Swedish capital city is located there, and that the capital to a large extent is situated on a series of islands.

Figure 1 to the right further illustrates the distribution of the built environment along the Swedish coast, showing the percentage of coastline affected by buildings for Swedish municipalities situated along the coast (Statistiska Centralbyrån, 19 October 2011, p 26). Here we can see that the municipalities the most affected are situated along Norrlandskusten in the north, around Stockholm and Malmö, as well as along Blekinge coast in the south. This distribution well reflects how the Swedish population is distributed. In general, counties with a long coastline also tend to have a high proportion of their buildings along these coastlines (Statistiska Centralbyrån, 19 October 2011, p 4).

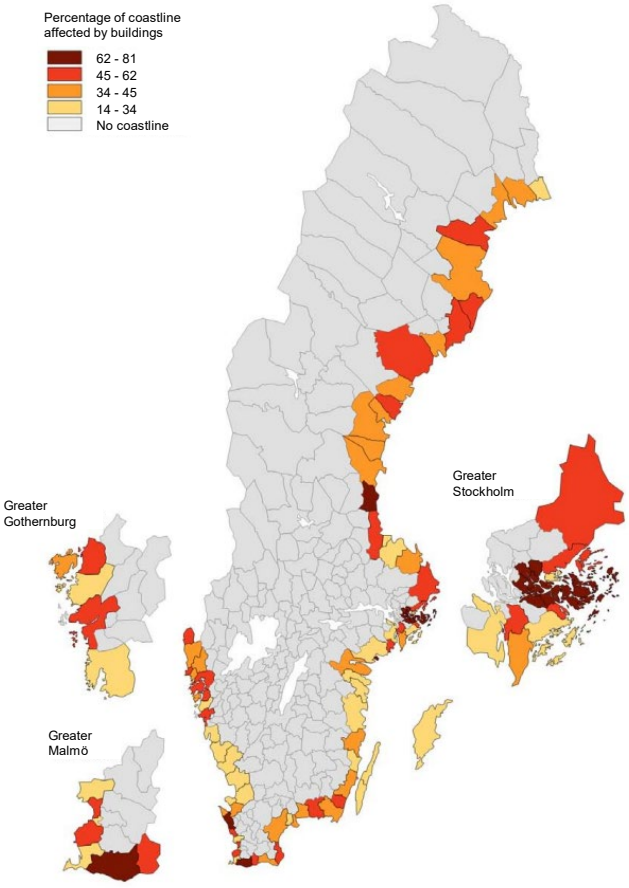

Figure 1. Percentage of coastline affected by buildings, per municipality.

In addition to buildings located on the coast of the mainland, many Swedish islands also accommodates built environment. Sweden has around 270,000 islands in total, whereof 8,000 hosted some type of building as of 2013 (Statistiska Centralbyrån, 8 December 2014). A mere 1,000 of these islands have inhabitants year-round, representing only 0.4% of the total amount of islands. However, 1.6 million Swedes, or 17% percent of the Swedish population, lives on islands, many of them in Stockholm and Gothenburg (Statistiska Centralbyrån, 8 December 2014). While 17% of the Swedish population lives on islands, the National Board of Housing, Building and Planning confirms that 40% of the Swedish population lived within five kilometres of the coastline as of 2013 (Boverket, 2013, p 18). This proportion is also increasing, as 97% of the total increase in population from 1995-2005 took place in this coastal zone (Boverket, 2006, p 27).

While the Swedish coastline is long and the Swedish population is relatively small from an international perspective, pressure on the Swedish coastline in terms of housing, recreation, tourism, and industries such as fishing, transport and energy is thus high (Boverket, 2006, p 23). Life along the coastline is also changing at a high pace, which means that the landscape may be altered and the ecological, social, cultural, and economic conditions in the future may be different (Boverket, 2006, p 24). For instance, the western coast, the coasts of Skåne and Blekinge as well as Stockholm archipelago are experiencing high pressure in terms of people moving there and new buildings being built, with half of all new buildings in the south of Sweden being built within the coastal zone (Boverket, 2006, p 25 and 30). As pointed out by the County Administrative Board of Blekinge county, many cities expand at the expense of areas of environmental value, in the case of Blekinge old forests with deciduous

trees. Another trend is that previously temporary houses along the coast are turned into permanent housing (Boverket, 2006, p 26). This means that the built environment changes as buildings become bigger and the cultural environment is altered, and naturally a greater need for infrastructure and communication follows.

3 Climate change evidence in coastal regions

3.1 Changing weather patterns

Changes in the Swedish climate are similar to climate changes that have been observed in other places in the world (Naturvårdsverket, 19 February 2021). Given vast differences in geography, however, there are already great variations with regards to climate and weather between various places in Sweden, and the Swedish climate also normally varies greatly from one year to another. These variations entail difficulties in discerning long-term changes in the Swedish climate as such long-term changes are blurred by the normal annual and geographical variations (Naturvårdsverket, 19 February 2021).

Certain evidence of a changed climate has however been observed across the country, including in coastal regions, and are to be expected also in the future. Changing weather patterns caused by climate changes relate mostly to changes in precipitation and temperature (Naturvårdsverket, 22 June 2020):

- **A change in temperature across the country:** Temperatures have increased and are expected to continue to increase across the country, and especially in the northern parts during the winter season (Boverket, 1 April 2020a). Likewise, an increase in heat waves is to be expected in the future, a hazard which will affect southern regions in particular. Increased temperatures will also result in a change in climate zones across the country - climate zones will "move" northwards, i.e., northern parts of Sweden are to expect a climate similar to today's climate in the south (Naturvårdsverket, 22 June 2020).
- **A general increase in precipitation across the country and across seasons:** A certain increase in precipitation has already been observed, and precipitation is expected to increase in the future across seasons, except during summers. Summers are instead expected to become hotter with less precipitation, in particular in the southern areas of Sweden. With increased precipitation levels in general also comes an increased frequency of periods with heavy rainfall.

Changing precipitation and temperature patterns bring with them negative effects on the weather in general. As will be elaborated upon in sections further below, these changes in turn bear with them consequences for the built environment, vulnerable coastal eco-systems, industries and biodiversity.

3.2 Temperature variations

Temperature variations in Sweden during the past century largely mirror global variations (e.g. that temperatures at the end of the 19th century were colder than during the 20th century), but overall, the warm-up has been more severe in Sweden than globally (Naturvårdsverket, 19 February 2021). From the end of the 19th century up until the 1930's temperatures rose across Sweden (in particular in the north were temperatures increased by 2.5 degrees Celsius), whereafter a slight decline in temperatures could be observed until the 1980's (SOU 2007:60, p 115). Thereafter, temperatures have once again risen – winter temperatures have increased by one degree on average compared to temperatures 100 years ago, and 2020 was recorded by SMHI (the Swedish Meteorological and Hydrological Institute) as the hottest year since the 1860's (SOU 2007:60, p 115; Naturvårdsverket, 19 February 2021). Changes have been even greater seen from a shorter perspective: on average, winter temperatures increased by two degrees in 1991-2005 as compared with 1961-1990 (SOU 2007:60, p

115). Variations in summer temperatures are not as great, although the overall increase in temperature is still evident.

As mentioned in the previous section, the above-described temperature increases have resulted in a change in climate zones in Sweden, where northern areas have started experiencing average temperatures similar to those in the south. To exemplify, these increases have resulted in that Mälardalen, a county located around Stockholm, will experience average temperatures to those of Skåne county in the very south, and the coast in the midst of Norrland (Mellersta Norrlandskusten) may expect temperatures similar to the coast in Småland county in the southeast (SOU 2007:60, p 160). Other effects of the increased temperatures include greater evaporation, shorter periods of snow and frost as well as shorter periods were lakes and watercourses are covered by ice, and elevated water temperatures (Livsmedelsverket, 21 January 2021). Combined, these factors contribute to inter alia an increased risk of overfertilization and increased humus levels in waters, which ultimately complicates the quality of the water and affects aquatic life.

Predictions for the future forecast an even greater increase in winter temperatures, to a large degree caused by the fact that the duration and thickness of the snow cover decreases (SOU 2007:60, p 160). These changes will be the greatest along the northern coast (Norrlandskusten), where they are contributed to by shrinking ices in the northern part of the Baltic Sea. Summers are also expected to become warmer, with climate changes resulting in an increase in hot days with a maximum temperature above 20 degrees Celsius (SOU 2007:60, p 164). Increasing summer temperatures are followed by an increase in heat waves, with heat waves both becoming more frequent and longer.

3.3 Precipitation changes

An increase in precipitation has been observed over the course of the past 100 years, although variations across the country have been great (Naturvårdsverket, 19 February). Precipitation is expected to continue to increase during the upcoming century, by as much as 10-20% (Länsstyrelserna, 2012 p 18).Increases have been observed across seasons but are the greatest during winter (Världsnaturfonden, n.y.).During summers, precipitation is expected to increase in the north but decrease in the south – in both cases, an increase in heavy or extreme rainfall is to be expected (Länsstyrelserna, 2012 p 18).

In a cold country like Sweden, changes in precipitation do not only entail changes in rainfall, but also changes in snow fall and ice coverage. While warmer winters have already brought less snow falling, predictions for the future are that the season when snow covers the ground will become shorter, and also that the snow coverage will become less thick (Länsstyrelserna, 2012 p 18). This is particularly true for the Svealand region and coastal areas in the north, which may expect a shortening of two to four months of the snow season. Such changes in turn affects water levels and flow in many watercourses, which are dependent on when the snow and ice is melting, and how much of the ice and snow is melting. Particularly in the north where many great rivers are located, this affects the flow of fresh water into the sea.

Precipitation changes together with the above-described changes in snow fall, ice coverage and evaporation also entail consequences with regard to the access to water, both in watercourses and at ground level (Livsmedelsverket, 21 January 2021). In the future, access to water is expected to increase in large parts of the country, except for in the southeast, where access is expected to

decrease because of increased evaporation. Effects on ground level water has implications on the access to drinkable water, which may be complicated in the future.

3.4 Sea level rise

Globally, sea levels have risen at an average of 1.9 centimetres per decade, a trend which is reflected in Swedish coastal areas (Sveriges Vattenmiljö, n.y. a). Again, local differences are to be observed, which is due to tectonic uplift - as a result of being covered with thick layers of ice during recent ice ages, the Swedish crust is rising upwards. This uplift is mitigating the rise in sea levels, and its pace differs greatly depending on what area of Sweden is observed. To illustrate, northern coasts in Sweden around the Bothnian Bay may expect a 22-33 centimetre sea level rise by 2100, whereas the corresponding number for coasts in Skåne in the very south may be as large as 77 centimetres by that same year (Sveriges Vattenmiljö, n.y. a). This is because the crust in the north of Sweden is still rising with relative speed, whereas the tectonic uplift in the south has come to a standstill. These differences also entail that consequences of climate change and rise in sea levels, such as coastal erosion and flooding, differ depending on what part of Sweden is observed.

Increasing sea levels are coupled with an increase in surface water temperature in Swedish coastal waters. Here, Swedish increases do not reflect increases globally, but rather surpass them. Whereas a future global average increase of 0.09-0.13 degrees Celsius per decade is to be expected, temperatures in Swedish waters will increase by 0.2-0.5 degrees Celsius per decade (Sveriges Vattenmiljö, n.y. a). As will be further discussed below, these changes have implications for flora and fauna in and around Swedish water, given the unique and delicate nature of the Baltic Sea which to a large part surrounds the Swedish coastline.

4 Disaster risk and climate change

A report titled *Swedish crisis management and the indirect effects from climate change*, the Swedish Defence Research Agency discusses the challenges that Swedish disaster risk management faces with regards to the indirect consequences that follow from climate change, as well as how Swedish society may handle these challenges. The report identifies six groups of general challenges related to Swedish disaster risk management and climate change, where the main challenges lie in handling previously unknown situations and risks, as well as in how to prepare the Swedish people mentally in facing such situations and risks (Mobjörk, 2011 p 32-33):

- Firstly, warmer temperatures and a changed climate bring with them previously unknown situations and consequences, which indirectly affect Sweden by for instance impacting conditions for production of food and goods or on relations and cooperation between municipalities, regions, agencies and other nations.
- Secondly, rising sea levels and changes in watercourses (such as elevated water levels, increased risk of inundation and flooding) entail fundamental and encompassing changes the final consequences of which are still unknown, and which require society to react and act in due time in order to mitigate their potential negative effects.
- Thirdly, vast regional, geographical and social differences have to be taken into consideration in disaster risk analyses, as well as how climate change consequences affect different groups in society.
- Fourthly, a social challenge will be the mental capacity of the Swedish people to confront large-scale and swift changes, such as crises or serious disturbances both within and outside the country.
- Fifthly, risks related to long-term, large-scale climate changes are brought to attention, as they may entail that drastic economic and social measures have to be taken in order to mitigate them. Risks and insecurities related to geoengineering are brought to attention in relation to this, as although this type of engineering may be relevant with regards to mitigating acute risks associated with great uncertainties.
- The final challenge focuses on the impact of climate change on the extent of disasters as a consequence of an increase in frequency and intensity of extreme weather. Natural hazards such as inundation and landslides are deemed a great risk, with potentially devastating impacts on infrastructure and on the built environment.

These are challenges which all sectors will face with regards to disaster risk management, as they relate to climate change consequences at large. In mitigating or preparing for the hazards or vulnerabilities accounted for below, these challenges thus have to be taken into account.

4.1 Hazards

Due to the country's abundant coastline, many hazards identified for Sweden as a whole also affect Swedish coastal areas. Climate change induced hazards much follow as a consequence of the changes in weather, temperature, precipitation and sea levels that were discussed in section 3.

- **An increased risk of inundation:** The increase in precipitation, which is also coupled with an increase in intense rainfall, will increase the risk of inundation and flooding (Naturvårdsverket,

22 June 2020). Because of warmer winters and increased precipitation, Sweden has during the past 30 years already experienced a remarkable amount of flooding, coupled with elevated inflow levels to lakes and watercourses since the mid-80s (Naturvårdsverket, 19 February 2021). This trend is expected to continue in the future, and it puts at risk both the built environment and people living close to watercourses and the sea. Currently, around 1 percent of all buildings, or 11.1 km^2 of land with buildings, not accounting for industrial areas, lies in areas which risk inundation (Boverket, 2013, p 18).

- **An increased risk of erosion and landslides:** Increasing sea levels will in the future cause the coastline to advance inland (Boverket, 22 December 2020). This means that beaches which today experience only moderate erosion in the future may experience more extensive erosion. This poses a severe risk to buildings and humans alike situated close to the current coastline. The risk for landslides likewise increases as erosion destabilizes the soil, a risk which moreover is exacerbated by increasing precipitation and heavy rainfall.
- **An increased risk of heat waves:** As mentioned above, heat waves are expected to increase in the future, as a direct consequence of the general increasing temperatures. These changes will be the most prominent in the south. This presents a danger to vulnerable ecosystems as well as human health, with heat waves potentially causing an increase in fatalities.
- **A shortage of water and droughts in southern Sweden:** Although precipitation is expected to increase in general, summers are expected to become hotter, and especially in the south. This may entail an increased risk of droughts and a shortage of water in the south (Naturvårdsverket, 22 June 2020). Droughts as well as a shortage of water mainly affects agricultural production, but also access to drinkable water and its quality.
- **Shrinking Swedish glaciers and changes in ice melting patterns:** As a direct consequence of the changes in temperatures, Swedish glaciers seem to be shrinking, and changes have been observed with regards to when the ice is melting in big lakes and rivers (Naturvårdsverket, 19 February 2021). During the past 40 years it has been observed that the ice is melting on average 20 days earlier in the south, and nine days earlier in the north. Importantly, the sea ice which normally covers large parts of the Baltic Sea stays for shorter periods of time – over the course of the 20th century, the duration of the sea ice has shortened by between 14 and 44 days (SMHI 27 May 2020). This mainly has implications for life in the Baltic Sea, as many species directly and indirectly depend on these ices for living and reproduction.
- **Increased spread of pollution:** The spreading of pollutants and contamination comes as a risk from inundation, heavy rainfall and elevated water levels in watercourses (SOU 2007:60, p 340). Pollution may come in the shape of metals, chemicals, or organic substances, or even diseases. Fluctuating ground water levels affect chemical conditions in the ground and cause soil-bound pollutants to become more mobile, and chemical substances or diseases may be freed by erosion and landslides. The spreading of pollutants poses a hazard to inter alia sensitive ecosystems, the quality of drinking water, the fishing industry and farmlands.

4.2 Vulnerability

Certain factors increase the susceptibility or vulnerability of the Swedish community with regards to the above-described hazards:

- **Particularly vulnerable ecosystems:** As mentioned above, Sweden is surrounded by the Baltic Sea, whose flora and fauna are vulnerable to changed weather conditions and climate changes due to the Baltic Sea's unique conditions. Only a few species can survive in these brackish conditions which moreover are characterised by large differences in salinity from one region to another. To illustrate, the number of species around the Swedish coast falls from almost 1,000 in the Kattegat on the west coast, to just 50 in the Gulf of Bothnia (Skansen, n.y.). The Baltic Sea is therefore a very species-poor ecosystem where many species are close to their distribution limit, factors which contribute to the highly sensitive nature of the eco-systems here.

  The only inflow of salt water to the Baltic Sea happens when water from the Atlantic manages to cross the high thresholds of the Danish straits. In this way, it would take around 30 years to replace the water in the Baltic Sea with oxygen-rich salt water (Skansen, n.y.). This means that pollutants released into the Baltic Sea remain there for a very long time - a factor which, in combination with the fact that coastlines around the Baltic Sea in general are highly industrialized, further contributes to the vulnerability of the eco-system in the Baltic Sea.

- **Inadequate infrastructure:** Old roads and other infrastructure are vulnerable to precipitation and climate changes as changes in pressure caused by altered water levels were not taken into consideration when constructing this infrastructure (SOU 2007:60, p 199). Older bridges are vulnerable as they may not be built sufficiently high above watercourses, and likewise bridges that are not sufficiently anchored in the ground (SOUR 2007:60, p 201). Security marginals are thus too low for such infrastructure. The vulnerability aspect here lies in the fact that it to a large extent is unknown what parts of the current infrastructure has too low security marginals.

- **Infrastructure located below future sea levels:** Certain infrastructure is located near or below predicted sea levels in the future. This puts them at risk for inundation. For instance, rising sea levels are a threat to low lying roads and tunnels in the south of Sweden (SOU 2007:60, p 201).

- **Inadequate water infrastructure:** Current infrastructure for purification of drinking water use simple treatment techniques, which are adapted to water which is already of good quality (SOU 2007:60, p 278). A deterioration of the water quality, for instance caused by increased humus levels or microorganisms, or chemical pollution caused by extreme precipitation, rainfall or inundation, complicates this purification process. Distribution infrastructure is also vulnerable to rainfall and inundation/landslides. In addition, increased temperatures increase the risk for diseases, viruses and parasites carried by the drinking water (SOU 2007:60, 280). Current purification methods are close to non-effective when it comes to combatting these hazards, which further increases vulnerability with regards to provision of drinking water. Thus, current purification methods will in many cases not be sufficient in a scenario with continued climate changes.

4.3 Exposure

Certain areas of Sweden are more exposed to issues such as rising sea levels, inundation, erosion, and landslides than others. Around 40% of the Swedish coast accommodates buildings less than 100 meters from the shoreline, corresponding to around 120,000 buildings situated within such coastal areas (Länsstyrelserna, 2012 p 21), and around 3.2 million buildings are situated within five kilometres from the coastline (SOU 2007:60, p 333). Along the western, southern, and south-eastern coasts of

Sweden as well as in Stockholm archipelago, a great part of buildings is situated less than five meters above current sea levels (SOUR 2007:60, p 297). In Skåne, this amounts to around 30% of the total surface accommodating buildings. Although current forecasts predict sea levels to rise only with 0.8-2.0 meters (SOU 2007:60, p 297), it is easy to imagine the potentially devastating risk that rising sea levels and following climate change induced disasters such as inundations, erosion and landslides poses to the Swedish building stock.

Skåne is in general one of those areas which will be the most exposed and vulnerable to climate change related consequences in the future (Länsstyrelsen I Skåne Län, 2011 p 17). Large parts of its coastal areas are already built, and they are moreover highly exploited. It is also one of the areas most exposed to coastal erosion and rising sea levels, with close to one meter sea level rise expected by 2100 (Länsstyrelsen I Skåne Län, 2011 p 17). Almost all of Skåne county's 33 municipalities are currently experiencing problems with increased precipitation and the pressure that follow on water infrastructure (Länsstyrelsen I Skåne Län, 2011 p 21). Evidence of erosion can moreover already be found along the southern coast of Skåne, where in some places the shoreline has shifted over 200 meters inland over the course of the past 40 years (Malmberg Persson, Nyberg, Ising and Rodhe, 2016). These shifts bring with them issues such as flooding of low-lying areas, erosion of beaches as well as saltwater intrusion in ground water reserves close to coastal zones, and has implications for planning of the built environment. Under current conditions, 12% of beaches in Skåne are experiencing net erosion, i.e. losing sediment at a greater pace than they are accumulating, although a majority of beaches are experiencing erosion and accumulation of sediment alternately (Sveriges Geologiska Undersökning, 7 April 2020):

Current erosion conditions along the coast of Skåne		
Accumulation/Erosion	Percentage of beaches	Total length in kilometres
Accumulation	7 %	37 kms
No erosion	5 %	25 kms
Insignificant erosion	24 %	134 kms
Balance between erosion and accumulation	31 %	175 kms
Slow erosion	5 %	28 kms
Significant erosion	7 %	39 kms
No data (ports, urban settlements, etc.)	21 %	117 kms

Table 1. Current erosion conditions along the coast of Skåne, as measured by the Geological Survey of Sweden.

As an example, certain calculations predict that if all watercourses mapped according to their risk for inundation were flooded, damages inflicted on existing buildings would amount to 18 billion Swedish kronor (Länsstyrelserna, 2012 p 19). Other calculations looking at the costs induced by rising sea levels around the country predict that damages on buildings in Ystad municipality would amount to at least 172 million kronor if sea levels were to rise two meters, and in Gothenburg a 0.9-meter rise would inflict damages of 7.5 million kronor (SOU 2007:60, p 298). As rough as these estimates may be, they still give a general idea of how serious the risk of rising sea levels is, and how great the damages to the built environment may become.

5 Climate Change Impact in Coastal Regions

Areas along the Swedish coast are mainly affected by rising sea levels, increased erosion of coastal areas, warmer waters, increased sea acidification, changing salinity levels in the sea, longer dry periods, and inundation as caused by an increase in precipitation and heavy rainfall (Boverket, 1 April 2020a). The consequences of these factors are many: the built environment is affected in exposed coastal areas experiencing rising sea levels and which are prone to erosion; and rising water temperatures, increased sea acidification and changes in salinity affect vulnerable ecosystems in the marine environment, which in turn has an impact on industries based on marine ecosystem services (Boverket, 1 April 2020a). Overall, the negative consequences of the changes in the climate are considerable, both within the foreseeable future and in the long term. In addition, these issues are further exacerbated by the fact that much of the Swedish coastline is surrounded by the Baltic Sea, which because of its semi-inland sea characteristics hosts many particularly vulnerable ecosystems and species (Boverket, 1 April 2020a).

5.1 Physical impacts

Inundation and increasing sea levels

Increases in precipitation (as mentioned in section 3.3) is followed by an increased risk of inundation and flooding (Naturvårdsverket, 22 June 2020; Livsmedelsverket, 21 January 2021). Lakes and other watercourses are experiencing huge inflows of water (e.g. from melting snow or from heavy rainfall) which in turn increases the probability of inundation. Along the coast, increasing sea levels contribute further to this problem, along with preventive measures such as embankments and removal of certain sections along watercourses which have a dampening effect on the flow of water (Livsmedelsverket, 21 January 2021).

The possible consequences following from an increased risk of inundation are evident. Apart from direct implications on the built environment in terms of effects on buildings, roads, railways and sewage systems, sources of drinking water also risk becoming affected (Naturvårdsverket, 22 June 2020). Water sources risk becoming polluted by flooding, and pipelines risk destruction. Developments of the built environment therefore need to take these factors into consideration. Sweden has since the year 2000 experienced many cases of inundation caused by increased periods with precipitation and instances of heavy rainfall (SOU 2007:60, p 132). These occurred across the country and showed inter alia that there are certain security risks following from inundation in Stockholm. They also caused extensive damages to important infrastructure in several areas. Roads were hit hard by inundation and elevated water levels, and damages in the shape of demolished railway banks, track movements, reduced bearing capacity and flooding of tracks were inflicted upon the railway infrastructure. To exemplify, the then existing Swedish Rail Administration's examination of damages between 2000 and 2001 showed a total of 200 damages of various kinds (SOU 2007:60, p 133).

Erosion of coastal areas and landslides

Erosion is expected to increase in coastal areas as a consequence of rising sea levels in combination with harsher weather, and in particular in southern parts of Sweden where the soil is particularly prone to erosion, such as Skåne, Halland, Öland and Gotland (Malmberg Persson, Nyberg, Ising and Rodhe, 2016; SOU 2007:60, p 136). For Sweden as a whole, around 15% or 1,800 kilometres of Swedish coastlines are prone to erosion of beaches (SOU 2007:60, p 313).The areas around Stockholm and

Norrlandskusten are moreover prone to landslides, as the soil to a large extent consists of mud (SOU 2007:60, p 135). More than 55 landslides of above one hectare in size has happened in Sweden over the course of the past 100 years, whereof at least three took human lives (SOU 2007:60, p 135). In 2006, there was a big landslide in Munkedal on the Swedish west coast, inflicting damages on people and important infrastructure. Damages to roads, railroads and telecommunication cables took close to two months to address.

Erosion along the coast poses a potentially devastating problems to many areas accommodating houses of varying types. Calculations made predict that a total of 1,135 km^2 of land lies within the risk zone for erosion from 2071-2100, corresponding to 222 km^2 of low buildings, 84 km^2 of holiday homes, 62 km^2 of industries and 0.5 km^2 of high buildings (the rest being cultivated land, etc.) (SOU 2007:60, p 317). 60% of this surface is located in Skåne county. In the below table both the number of current[3] buildings that are expected to be threatened by erosion of beaches in 2071-2100, and their corresponding value (SOU 2007:60, p 317-318). In addition to damages on actual buildings, there will also be damages to local infrastructure such as streets, water, sanitation, electricity, and communication.

Type of building	Number of buildings	Value of buildings/land (million SEK)
Low buildings	116 900	168 400
Holiday homes	32 400	33 900
High buildings	100	1 200
Industries	3 500	16 900
Farmland		4 000
Total	**152 900**	**224 400**

Table 2. Number of current buildings threatened by an increased risk of erosion along beaches from 2071-2100, and their corresponding value in million Swedish kronor.

Saltwater intrusion and changes in groundwater levels

As mentioned above, Sweden has experienced an increase in precipitation over the course of the past century, a trend which is expected to continue in the future. In large parts of Sweden, this has led to an increase in both the lowest and the highest groundwater levels from 1975-2014, where the largest increases have been observed in coastal areas (Sveriges Geologiska Undersökning, 17 January 2018). In the future, the formation of groundwater is expected to increase by 15% in the north and decrease with 5-15% in the southeast of Sweden (Sveriges Geologiska Undersökning, 17 January 2018).

Decreased groundwater levels, contributed to by a drier climate during summers because of increased temperatures, may in the south have negative consequences in terms of saltwater intrusion and access to fresh water. Decreased groundwater levels bring with them the risk of saltwater intrusion both in watercourses and water reservoirs, which inter alia complicates access to water suitable for drinking and irrigation. This further worsens the increased need for water for irrigation which follows from a drier climate and increased temperatures during summers.

Decreased groundwater levels have already been observed in coastal regions in the south – such as Blekinge, Öland and Gotland – with saltwater intrusion from the Baltic sea as a result (Världsnaturfonden, n.y.). As a result, freshwater reserves are in danger.

[3] As of 2007.

Changes in salinity and sea acidification

If hotter summers create issues of saltwater intrusion in groundwater in the south, increased precipitation levels in general bring with them another saltwater related problem. An increased outflow of freshwater from land contributes to decreased salt levels in the sea, an issue which is particularly problematic for the Baltic Sea which to a large extent is confined by land borders, and which only receives an inflow of saltwater from the Atlantic via Kattegat (Boverket, 1 April 2020a).

Ecosystems within the Baltic Sea are highly vulnerable and many species, for instance cod, are highly dependent on specific salt levels for reproduction and living. The potential negative effects of decreased salt levels on life both in the sea and along the coast in the Baltic Sea are thus worthy of consideration. Luckily, no clear trend of decreasing saltwater levels in the Baltic Sea has been observed so far (Sveriges Vattenmiljö, n.y. a). A potential explanation for this may again be that long-term impacts of a changed climate are blurred by local and seasonal variations – approximations estimate that climate changes are responsible for a 0.3 PSU (Practical Salinity Unit) decrease per decade, whereas local and seasonal variations may be as large as 18 PSU (Sveriges Vattenmiljö, n.y. a).

Life in the Baltic Sea is not only threatened by changes in salt levels. Recent measurements have demonstrated acidification of Swedish waters, caused by increasing levels of carbon dioxide in the atmosphere dissolving into the seawater. This further stresses the already delicate ecosystems existing in the Baltic Sea, as sea acidification increases the solubility of lime (a type of stone which is abundant in Swedish coastal areas such as Skåne, Gotland and Öland [Svenska Kalkföreningen, 2020]) and moreover poses difficulties for marine organisms in terms of building up shells and skeletons (Boverket, 1 April 2020a).

5.2 Environmental Impacts

Impacts on ecosystems and natural habitats

Species and ecosystems respond to the physical and chemical changes in their environment that are caused by climate change. For instance, the UN Panel on Climate Change states that many species living on land, on fresh water and in the sea have shifted their geographical habitats, seasonal activities, migration patterns and interactions with other species as a response to these changes (Havs- och Vattenmyndigheten, 3 March 2017). Sweden poses no exception to these observations. It is surrounded by the Baltic Sea, whose environment is unique because of its brackish water. This unique environment also means that many of the ecosystems and species in the Baltic Sea are unique, and therefore are highly susceptible to any changes in the climate. Current predictions expect the Baltic Sea to be even more affected by climate changes during the course of the next decades, and therefore, effects on marine ecosystems and on biological diversity in Swedish waters and around Swedish coasts are highly probable (Sveriges Vattenmiljö, n.y. a).

The above-described changes in precipitation and temperature levels have had impacts on vulnerable ecosystems along the coastline and in the Baltic Sea, as well as has caused changes in natural habitats for certain species. Increased temperatures and heat waves have caused a change in habitat of several species of fish, which have migrated northwards (Sveriges Vattenmiljö, n.y. a). Cold-water species have been particularly vulnerable to the warm-ups, and this has had spill-over effects on the fishing industry which to a large degree is dependent on these species (Boverket, 1 April 2021). Immovable species, such as corals, are also among the most affected, as they experience increased stress levels

because of the increasing temperatures (Boverket, 1 April 2021). Moreover, changes in the level of salinity affects important species such as eelgrass, sea mussel, cod and certain crustaceans, the habitats of which are determined by levels of salinity (Sveriges Vattenmiljö, n.y. a).

Impacts on biodiversity

As habitats and ecosystems are affected by climate change, effects on biodiversity follow. Increased temperatures both in water and on land shift natural habitats northwards, which means that southern species are migrating northwards while northern species being pushed aside (Naturvårdsverket, 22 June 2020). Biodiversity is thus affected as new species may establish themselves in areas where they previously have not been present, or as rare species may disappear along with their natural habitats or because new species take over.

In the sea, biodiversity is affected by increasing temperatures, eutrophication, and changes in salinity and because of the fact that the ice in the Baltic Sea is shrinking. Among species affected by these changes are cod, as its reproduction areas, which are dependent on salinity and oxygen levels, are shrinking (SOU 2007:60, p 386). This species may be completely eliminated from the Baltic Sea, which also will impact the Swedish fishing industry heavily. Other species such as turbot, flounder, plaice, sandpiper, herring and sprat may likewise be negatively affected (SOU 2007:60, p 386).Furthermore, it is expected that the ice will shrink substantially, to the extent that at the end of this century it will only exist up in the far north. This has implications for the ringed seal, which is expected to decrease in population (Sveriges Vattenmiljö, n.y. a). In addition to being affected by the climate changes themselves, biodiversity may also be affected by society's attempt at mitigating the climate changes (SOU 2007:60, p 414). This may for instance entail a shift in the use of resources, adjustments of lakes and watercourses, or a change in emissions to waters and land. Biodiversity in Swedish coastal areas is for instance impacted by changes in land use for cultivation, as facilitated by warmer temperatures and increases in precipitation (Naturvårdsverket, 17 February 2021). More land may be used for cultivation of crops or abandoned meadows and pastures may be overgrown, which threatens biodiversity in the agricultural landscape.

Impacts on algae and seabeds

The section above mentions how coral are particularly susceptible to increasing water temperatures, as they normally are stuck and cannot move to colder waters. Many water-bound creatures are dependent on water temperatures for their living, and also on how seasonal variations in temperature affect the movements of the water (Livsmedelsverket, 21 January 2021). This is why increasing temperatures in combination with shrinking ices may bear great consequences for ecosystems and species in the sea and along the coast, mitigating the seasonal variations. Along the Swedish coast algae are affected, both in terms of blooming, but also in terms of composition of algae species (Livsmedelsverket, 21 January 2021). In spring, blooming is expected to start earlier, although the total amount of algae blooming is expected to decline slightly. In contrast, blooming during autumn is expected to increase in magnitude.

Temperature changes thus have an impact on algae species, their blooming and on their spreading. Increased blooming moreover causes an increase in organic compounds, which inter alia complicates the purification of drinking water. The increase in organic compounds also entails an increased need for oxygen for decomposition of the compounds, which further complicates the quality of the water. Importantly, it also contributes to the problem of oxygen-deprived seabeds in the Baltic Sea

(Klimatanpassning.se, 12 November 2019a). Oxygen-deprived seabeds lack the ability to support a rich animal life, where animals flee the oxygen-deprived environment and immobile species die. Moreover, the lack of oxygen leads to the release of phosphates from sediment at the bottom, which is brought up to the surface where it contributes further to algae blooming (Klimatanpassning.se, 12 November 2019a). This is thus a circular system which consistently reinforces itself, with detrimental feedback loops both in the sea, where habitats of marine species are shrunk, and on land.

On land, blooming algae have negative spill over effects on human and animal health. As algae bloom, toxins which are detrimental to human and animal health are created (Livsmedelsverket, 21 January 2021). Common symptoms are nausea, vomiting, diarrhoea, fever, skin irritation and eye problems. Animals that drink from the water may become seriously ill or even die. This is thus an example of how marine and land ecosystems are highly connected, and issues at sea cause problems on land.

Impacts on agricultural productivity

Skåne and Gotland are the Swedish counties which boast the largest proportion of agricultural land (45% of the total area for Skåne and 36% for Gotland) (Statistiska Centralbyrån, 15 October 2020). These counties are also located in the south and have long coastlines (in particular Gotland which is an island). Climate changes affecting coastal areas in particular therefore have the potential to impact greatly on agricultural productivity in these counties, and consequently also on agricultural productivity in Sweden in general. To exemplify, half of the food produced in Sweden comes from Skåne, and half of the Swedish food industry also stems from there (Region Skåne, 18 December 2020). It is therefore easy to imagine the impact that climate change consequences such as increased temperatures, worsened access to water for irrigation and coastal erosion, all of which are in particular affecting Skåne, could have on access to food and the agricultural sector in Sweden.

Climate changes have in Sweden affected agriculture both negatively and positively. On the positive side, increasing temperature and a hotter climate improve cultivation conditions, with possibilities for increased yields and for being able to farm crops for longer periods (Naturvårdsverket, 22 June 2020). On the other hand, warmer winters increase the risk for pests and carriers of diseases which normally would be mitigated by the cold, and as explained in the section on impacts on ecosystems, changed climate zones and shifting natural habitats also increase the risk for invasive species and weed (Mobjörk, 2011 p 20-22).

5.3 Economic Impacts

Impacts on maritime industries

Claims on and the use of Swedish coastal areas are increasing, for instance in terms of maritime industries such as fishing, shipping, offshore energy, electricity distribution, housing, and tourism (Boverket, 1 April 2020b). These industries are in many cases a prerequisite for thriving coastal communities. This puts pressure on the planning of marine and coastal areas as a variety of business interests have to be balanced with the long-term protection and sustainable use of the sea. At the same time, climate changes and their impacts on and consequences for these industries as well as the built environment supporting these industries have to be taken into account.

The Swedish fishing industry: The Swedish fishing industry is to a large extent dependent on the conditions in the Baltic Sea. This means that when the Baltic Sea in negatively impacted by climate

changes or by human behaviour, this also has the potential to impact the Swedish fishing industry in a negative way. As we have seen, many eco-systems and species in the Baltic Sea are fragile, and their natural habitats, population and reproduction are impacted by climate changes. The climate changes have so far entailed increased temperatures in the sea as well as certain changes in salinity because of increased outflows of water from the sea, which has had an impact on the geographical distribution of certain species, as well as their reproduction and access to food (Boverket, 1 April 2020b). As such, populations of fish are moving away from certain areas or diminishing in size, affecting how the fishing industry works. Already, there are evidence of how decreasing fishing populations have affected the Swedish fishing industry: from 1995-2002 the number of Swedish fishermen decreased from 2,900 to 1,900 and the number of fishing ships from 2,540 to 1,597 (SOU 2007:60, p 382). An increasingly hotter Baltic Sea in combination with desalination could in the future entail that important species such as herring, cod and salmon are completely eliminated, which would be devastating to the Swedish fishing industry (Naturvårdsverket, 15 April 2021). If cod were eliminated from the Baltic Sea, this may entail losses of around 200 million kronor per year for the Swedish fishing industry, or around 15 billion kronor until the year 2100 (SOU 2007:60, p 491-2).

Other issues, such as polluted water from cities caused by inundation or saltwater intrusion, may further complicate life for many species in the Baltic Sea as toxic substances end up in the water. As we have seen above, a growing algae population caused by climate changes also pose a problem to life in the sea, as seabeds are deprived of oxygen. In addition, changed water levels in many great rivers that flow into the sea may change the conditions for certain species of fish which move along the rivers for reproduction (SOU 2007:60, p 385). These are all consequences of climate change, and consequences which in turn will have an impact on the fishing industry.

Not only open water fishing is affected by these changes, but also the farming of fish and other species. In Scandinavia, fishermen farm mainly cold-water species such as salmon (Boverket, 1 April 2020d). Warmer seas may thus have a negative impact on the farming of these species. In addition, the pressure from parasites and diseases may increase as an effect of the warmer temperatures. Farming of other species, such as mussels and oysters are furthermore impacted by increased pollution and increased acidification of the sea (Boverket, 1 April 2020d).

Impacts on the Swedish tourism industry

While the Swedish tourism industry may actually benefit from climate change and warmer temperatures, coastal areas will experience increased pressure both from foreign and Swedish tourists, who are escaping hotter temperatures along the Mediterranean and inland Sweden (Boverket, 1 April 2020c). Increased temperatures mean a prolonged summer season and increasing water temperatures, which draw tourists to beaches and the sea. Increased tourism may also entail increased pressure on areas of environmental value and on vulnerable ecosystems along the coast, for instance in terms of emissions from boats, littering, noise, and general wear and tear of these areas. Moreover, we have seen that access to drinking water may become an issue because of hotter summers especially in the south, and this problem will only be exacerbated by an increased tourist population (Boverket, 1 April 2020c). So whereas the Swedish tourism industry will benefit from a larger clientele and a prolonged tourist season, the spill over effects of these changes on the environment are exacerbating an already unsounds situation.

In addition, the built environment along the Swedish coast is threatened by increasing sea levels, erosion, inundation and landslides, which means that the built environment supporting the increased

tourism is threatened. Erosion is moreover increasing the most along sandy beaches, which some places may disappear entirely. This could have a devastating impact on the Swedish tourism industry.

Economic impacts

Climate change and the many devastating events that potentially follow with it will put pressure on local and national governments alike in terms of preventive, mitigating, adaptive and reparation measures. An encompassing investigation issued by the Swedish Ministry of the Environment has estimated the costs associated with damages and remedies caused by climate changes or adaption to climate changes in various sectors (SOU 2007:60, pp 478). Costs for damages include those costs that would be inflicted to cover damages if no measures were taken to mitigate the consequences of various weather events (e.g., reparation or restoration of what has been damaged, or the value of what has been damaged in case reparation is not possible). Evidently, precise calculations are hard to perform, but the below numbers still give an idea of the magnitude of the costs associated with climate change mitigation and adaption:

- Costs for reparation damages to roads and bridges[4] caused by landslides, washed away roads or inundation is estimated at 80-200 million Swedish kronor per year, and may amount to as much as 9-13 billion kronor by 2100 if risks increase successively. This does not include costs for great landslides such as the one in Munkedal described in section 5.1, which ended up costing 120 million Swedish kronor. Costs aimed at preventing 50% of future predicted damages, on the other hand, are estimated at 2-3.5 billion Swedish kronor, suggesting great benefit with regards to preventive measures (SOU 2007:60, p 480-481)
- Adaptive measures taken to decrease the risks with regards to climate change impacts on railroads include inter alia education of workers, mapping of risk areas, increased maintenance, change of drainage systems and protection against erosion, an examination of current requirements for dimensioning, as well as maintenance of forests to prevent power failures. Costs related to such adaptive measures are estimated at 100 million kronor, with another 20 million kronor per year aimed at increased maintenance (SOU 2007:60, p 481).
- Decreasing ices along the northern coasts may affect the costs associated with icebreaking to facilitate shipping and seafaring. Currently, such costs amount to 150-250 million kronor per year. Here, climate changes may thus impact costs positively, in that decreasing ices yield decreasing costs for icebreaking (SOU 2007:60, p 482).
- As described in further detail in section 6.2, increased precipitation may put increased pressure on dams and waterpower reservoirs. Provided that current waterpower stations are rebuilt in order to handle the increased water flows, a 15-20 water flow increase could yield 190-260 billion Swedish kronor in increased earnings (SOU 2007:60, p 482). Of course, this has to be put against the potentially increased costs that come with mitigating and repairing damages inflicted by inundation and landslides.
- Costs related to pure maintenance of buildings as caused by climate change (increased temperatures and humidity) amount to around 100 billion Swedish kronor up until 2080 (SOU 2007:60, p 485). Costs to prevent damages from erosion and inundation on the built environment will in the short-term amount to 150-500 million Swedish kronor (SOU 2007:60,

[4] This is based on state-owned roads only – roads managed by municipalities or private roads have not been included in these calculations.

p 205). Likewise, costs to prevent landslides will amount to at least 200 million Swedish kronor. These costs do only take into account preventive measures, and costs on actual damages are not included. The investigation estimates that if all built environment located along watercourses and the sea and for whom the risk of inundation is high would be inundated, costs may amount to over 18 billion kronor just to restore this environment (SOU 2007:60, p 486). This does not include damages inflicted upon e.g., infrastructure, but only upon the buildings themselves.

- By the end of the 21st century, the number of buildings located within areas prone to landslides is estimated at 22, 000, at a value of 320 billion Swedish kronor (SOU 2007:60 p 489). To this can be added another 15 billion kronor for electricity and water infrastructure, as well as over 15 billion kronors worth of agricultural land or forests. Costs of landslides were to happen could therefore potentially be great. Likewise, around 150,000 buildings at a value of 220 billion kronor are located in coastal areas which are prone to erosion (SOU 2007:60, p 489).

The above represents but a mere fraction of the costs that could or would be caused by climate change induced consequences. Costs inflicted on various industries, on countering negative effects on human health, for covering rescue services and more have to be added to this.

5.4 Social Impacts

Physical health conditions, injuries and fatalities

Human health is affected by increased frequency of periods with extreme temperatures. Periods with extreme temperatures are increasing in Sweden, which has the potential to cause increased fatalities, especially amongst already vulnerable groups such as the elderly (SOU 2007:60, p 439). Days with extreme temperatures are increasing proportionally as compared with the rise of average temperatures, especially in the south and mid Sweden and along Norrlandskusten (SOU 2007:60, p 441). The below table illustrates what a future increase in fatalities as caused by increased summer temperatures could look like in Stockholm and its surrounding areas, compared with 1998-2003 and calculated according to two different scenarios[5] (SOU 2007_60, p 443):

Increase in temperature	**Increase in fatalities**		**By year**	
Degrees Celsius	*Number*	*Percentage*	*Scenario A2*	*Scenario B2*
1	29	1,2 %	2025-2040	2025-2040
2	60	2,4 %	2060-2070	2080-2090
3	94	3,8 %	2090	2100
4	131	5,3 %	2100	-

Table 3. Increased fatalities in Greater Stockholm for increased summer temperatures, as compared with 1998-2003

While increased temperatures in extreme cases cause fatalities, they also bring with them many other inconveniences. Increased temperatures entail increased body temperatures, blood circulation and sweating, which stresses the heart and increases the risk for dehydration (Centrum för Arbets- och Miljömedicin, 20202 p 4).The risk for heat strokes and heart failure similarly increases.

[5] Scenario A2 is calculated on an expected increase in temperature by 3-4 degrees by year 2100, and scenario B2 is calculated on an expected increase in temperature by 2-3 degrees by year 2100.

While hotter summers may bring with them an increase in fatalities and other inconveniences, warmer winters may actually bring with them positive effects on human health (SOU 2007:60, p 444). Cold related fatalities and frostbites decrease, and warmer winters may also help reduce the periods where health conditions such as chronic heart and lung diseases or rheumatic disorders are worsened.

In addition to temperature changes, changes in natural habitats of certain species may bring with them potential issues for human health (Naturvårdsverket, 27 October 2020). To exemplify, pollen allergies may be exacerbated as the length and intensity of the pollen season changes with warmer temperatures, and the habitats of pollen-producing species may change. Ticks and their diseases are another problem aggravated by changing temperatures. The spread of diseases is also affected by the increased risk of inundation and landslides, which moreover may increase the risk of pollution of drinking water (SOU 20067:60, p 452). Evidently, extreme incidents such as inundation and landslides also increase the risk for accidents where people may get injured.

Impact on mental health

Effects of climate changes on mental health covers two aspects: firstly, one has to consider the increase in mental health issues that comes with experiencing natural disasters such as inundation or landslides; and secondly, many also experience a sense of hopelessness and anxiety with regards to facing climate change, a struggle which for many individuals many seem desperate and hopeless (Centrum för Arbets- och Miljömedicin, 20202 p 5).

Displacement / Loss of neighbourhood

The built environment in Sweden is highly planned and regulated, with Swedish municipalities being responsible for investigating how planned neighbourhoods or other built environment are affecting the environment and in turn are affected by climate change (Klimatanpassning.se. 12 November 2019b). In addition, climate change and its impact are constantly monitored, for instance in coastal areas via the Environmental Surveillance Programme for coastal areas and the sea, which is carried out in collaboration between the Swedish Agency for Marine and Water Management and the Swedish Environmental Protection Agency (Naturvårdsverket, 27 November 2020). Moreover, the Swedish Meteorological and Hydrological Institute stores and develops information on weather, water and climate for various societal functions, industries, and society at large (SOU 2007_60, p 288). Its prognosis department is constantly prepared to issue warnings which would limit damages on humans, property, and environment, with regards to high water levels or heavy rainfall. These factors make it unlikely that climate change would impact neighbourhoods in such a manner that it would ultimately lead to the displacement of those living there.

Loss of employment

As we have seen in the section above, the fishing industry is heavily impacted by changing conditions in the Baltic Sea, and the Swedish fishing fleet has already decreased significantly as decreasing fish populations means decreasing livelihood resources for many fishermen.

5.5 Governance and Institutional Impacts

An increased need for climate change related risk analysis

According to the Swedish Planning and Building Act, municipalities are required by law to take climate change into consideration with regards to planning of the built environment (Klimatanpassning.se. 12 November 2019b). Municipalities are also required to evaluate climate related risks for the built environment, such as inundation, landslides and erosion, and how they plan to reduce or eliminate such risks.

In coastal areas, erosion may bring with it serious implications for the built environment (Boverket, 22 December 2020). The loss of land undermines existing buildings and may cause damages to the buildings themselves. This has implications for location of new buildings, investments, and risk analysis. In Sweden, responsibility lies with the municipality to investigate the appropriateness of the land and to show that the land is suitable for construction (Boverket, 22 December 2020). If protective measures against erosion are planned, several laws and regulations may have to be taken into consideration, such as the Swedish Planning and Building Act or the Environmental Code (SFS 1998:808) where the latter has to be consulted in case of considerable impact on the environment. Likewise, municipalities have to take rising sea levels into consideration in their planning of the built environment, for instance by identifying risk areas and identifying the need for protective measures such as protective walls or filling out beaches with sediment (Klimatanpassning.se, 12 November 2019b).

Via the Tort Liability Act (1972:207) the municipality holds general liability for damages caused by error or negligence in their exercise of authority, for instance with regards to matters of planning and building permits (SOU 2007:60, p 563). Thorough risk analysis with regards to climate change and their effects on the built environment is thus very much in the interest of municipalities, as this responsibility lies with the municipality for ten years from the date when the incorrect decision was taken.

An increased need for planning and cooperation

Sweden is divided into 21 regions or counties (an institutional unit larger than the municipalities and responsible for cooperation between municipalities). The law stipulates that these regions are supposed to work with spatial planning as a consequence of climate change – while some regions have to work with regional spatial planning (“regional fysisk planering”) as stipulated in the Swedish Planning and Building Act (SFS 2010:900), others work with more general development planning on a regional level (Boverket, 29 December 2020).

The Planning and Building Act stipulates that Stockholm and Skåne county, which are both counties with substantial coastal areas (especially Stockholm county which to a large degree is situated in the archipelago), are to work with regional spatial planning in order to deal with questions regarding the use of land and water (Boverket, 29 December 2020). This may for instance encompass questions touching upon infrastructure, adaption to climate change, preventative measures against inundation, and planning of housing or the built environment.

Moreover, the law suggests that both regional spatial planning and regional planning in general could take coastal planning (LIS-områden, loosely translated as “areas close to beaches”) in particular into consideration (Boverket, 29 December 2020). This as these areas may be of importance for the development of the countryside, and because developments in such areas in one municipality may

affect similar areas in other municipalities. Both with regards to coastal areas and with regards to regional planning in general, climate changes have entailed an increased need for planning and cooperation, both between municipalities and regionally (Boverket, 29 December 2020).

Despite the increased need for risk analysis described above and the increased need for planning, investigations show that climate changes make it increasingly difficult to analyse, plan and cooperate (SOU 2007:60, p 564). Difficulties relate to knowing what future scenarios should be taken into account. Difficulties also moreover lie in weighing the potential risks associated with inundation and erosion against the fact that buildings close to waters and the coast are highly sought after. A city along the southern coast of Sweden, Ystad, functions as an illustrating example of how climate change impact on local government planning and investment (Klimatanpassning.se, 20 August 2018). Ystad has for a long time been troubled by increasing erosion along the coast, which is predicted to increase because of rising sea levels. Because of its location right by the sea and because of the role that the coastal areas play in recreation and the economy of the city, it was decided that the city would artificially restore parts of the coastline by adding sediment and sand. This was done for the first time in 2011, and restoration is now planned every third year. The financial implications of the restoration itself are not tremendous – 10,000 Swedish kronor have been allocated in the city budget for each round of restoration. However, investigations and research which form the basis for the permits needed to perform this kind of restoration have costed the city 3 million Swedish kronor. This is thus an example of how the negative implications of climate change may impact local level financing and economies.

6 Climate change impact on built environment in coastal regions

6.1 Impact on district level / city level

The current built environment is adapted to current weather and climate conditions (Klimatanpassning.se, 3 November 2020). Future climate conditions, such as increased temperatures and changed precipitation patterns, both require adaptation of future buildings and city or district planning with a focus on flexibility and sustainability (Klimatanpassning.se, 3 November 2020). For instance, increased precipitation, melting ice and rising sea levels entail that cities, districts and buildings close to the coast and shorelines risk inundation and landslides. This both requires adaptation of existing built environment, as well as it is a risk factor to take into account in the future planning of cities and districts. As current climate changes are not expected to stop within the foreseeable future, this also has an impact on the long-term planning of districts and cities. Many buildings and important infrastructure have a lifespan of 50-100 years and therefore require taking into consideration also future climate changes and what Swedish climate and coastal areas may look like in the future (Klimatanpassning.se, 3 November 2020). As mentioned in section 5.5, such scenarios are difficult to predict, which poses difficulties to effective planning on district and city level.

6.2 Impact on infrastructure

As we have seen, 40% of the Swedish population lives within five kilometres of the coastline, and a significant number of buildings are similarly located close to the Swedish coast. As societies and populations need infrastructure and communication to thrive, this also means that much important infrastructure is located close to the Swedish coastline. The below accounts for the consequences that climate change has had on infrastructure and communication networks in Sweden in general, but much of it holds for built environment located close to the coastline as well.

Roads

Important infrastructure such as roads and railways are often located close to watercourses, which means that they are vulnerable to increasing precipitation, inundation, flooding, and landslides (Naturvårdsverket, 31 March 2021). Precipitation affects road construction primarily via groundwater formation and via outflows into watercourses after heavy rainfall or melting of snow (SOU 2007:60, p 196). Increased precipitation may contribute to elevated groundwater levels and changed pressure in the soil, which affects slope stability, and high levels of water in watercourses similarly contribute to an increased risk of erosion (SOU 2007_60, p 196).Roads, banks and bridges may as a consequence be flushed away or damaged by landslides.

Increasing temperatures and shortened periods with frost may likewise affect this infrastructure, in places where such conditions have been taken into consideration during construction. General temperature changes affect the stability of roads and bridges. Another factor complicating road quality is the amount of times that temperatures shift from above zero degrees Celsius to below zero degrees Celsius (called “nollgenomgångar” in Swedish), as some constructions, e.g., concrete, are sensitive to such changes (SOUR 2007:60, p 202). The amount of nollgenomgångar is expected to increase in the northern and midst parts of Sweden as an effect of in general increasing temperatures.

Railroads

As with roads, railroads are sensitive to precipitation as it increases the risk of inundation, erosion, and landslides. Increased precipitation increases the risk for infiltration and erosion of ballast and constructions under the tracks, whose carrying capacity thereby decreases (2007:60, p 210). Low lying tunnels are sensitive to inundation, as are electronic devices and arrangements supporting the railways.

Increasing temperatures affect railroad tracks both in a positive and a negative manner, as increasing temperatures during winter may contribute to a decreased risk for tracks breaking, but on the other hand during summer may affect the tracks in such a manner that they twist or create so called “sun curves” (SOU 2007:60, p 206). In the long run, increased temperatures may increase the proportion of deciduous trees in the forest, which creates a risk as leaves falling make tracks slippery and thereby may cause traffic disturbances (SOU 2007:60, p 211).

Shipping and port infrastructure

Sea faring is not significantly impacted by the climate changes, except for in the north where it may be positively affected by decreasing ices, facilitating navigation and shipping.

Port infrastructure, on the other hand, is affected in various ways depending on where along the coast it is located (Naturvårdsverket, 31 March 2021). Generally, high water levels are better from a security perspective as it increases security marginals along fairways and in ports (SOU 2007:60, p 216). However, rising sea levels may cause existing infrastructure to fall under sea level, which evidently affects the functioning of the ports (SOU 2007:60, p 216-7). This risk is deemed the most likely in the south.

Dams and waterpower

Increased precipitation actually creates good conditions for Swedish waterpower, and especially for expanding already existing infrastructure (SOU 2007:60, p 234). However, investments and reconstruction efforts may have to be taken, as current facilities are fitted to current precipitation levels (SOU 2007:60, p 243). The size of spring floods, precipitation distribution across seasons as well as the capability of watercourses to handle increased levels are all factors which affect the amount of water that may be exploited for waterpower, and they are all in turn affected by the climate changes. In addition, electricity infrastructure may be affected, as an increased opportunity to exploit waterpower also poses increased demands on this infrastructure to bring electricity to other parts of the country (SOU 2007:60, p 249).

As with waterpower, dams are sensitive to the increased flows that come with changed precipitation levels, as these are often dimensioned taking current water levels and flows into account. (SOU 2007:60, p 255). If dams and water reservoirs are not dimensioned to handle the change in flows, inundation of nearby areas may be a risk (SOU 2007:60, p 261).

Provision of drinking water and sewers

The impacts of climate changes on the provision of drinking water are deemed to be significant (SOU 2007:60, p 277). This is both because a deterioration in quality of the water in reservoirs caused by increasing levels of humus and microorganisms, and because of an increased risk for rupture of infrastructure and pollution of the drinking water itself as caused by inundation or landslides. As seen in section 5.1, saltwater intrusion is another factor threatening this infrastructure, especially along the southern coasts.

Sanitation and sewers are likewise expected to become heavily affected by climate change because of increasing precipitation levels, overburdening current infrastructure (SOU 2007:60, p 323). Intense precipitation and heavy rainfall render increased volumes of water which current pipes and systems may not be adequate for, which increases the risk of inundation (SOU 2007:60, p 326). Likewise, increasing sea levels pose a problem to today's sewerage systems, as they may not be able to divert water properly if they find themselves under the sea level (SOU 2007:60, p 328).

6.3 Impact on Building Level

For buildings in general, increased temperatures, rising sea levels and precipitation changes bring with them issues such as an increased risk for inundation in basements situated close to the sea and watercourses; an increased risk for mold and problems with moisture in buildings; increased pressure on current sewerage systems; and an increased need for maintenance in general (Länsstyrelserna, 2012 p 23). The potential negative effects of the above-described climate changes on buildings can be summarized as follows (SOU 2007:60, p 335):

- Increased precipitation increases the risk for inundation of sewerage systems and basements, as well as the risk for landslides. It also increases wear and tear of external material.
- Increased frequency of heavy rainfall increases the risk for damages inflicted by mold and moisture, as well as damages on building materials caused by frost.
- Humidity is expected to increase in the north across the year. This entails increased risks for damages caused by moisture, corrosion, and frost, as well as increased degradation of external materials.
- A combination of increased humidity and increased temperatures renders an increased risk for mold, rot and insect infestation.

The above factors bear with them consequences for the durability of roofs, facades, windows, and house foundations, which will become increasingly worn and therefore require greater maintenance than before.

Impacts on cultural buildings and ancient monuments

Ancient cultural buildings and monuments are particularly vulnerable to the changes in climate, both because of their age but also because they are often placed in coastal areas (Naturvårdsverket, 31 March 2021). This means that they often lie within risk zones for landslides, erosion, or inundation. General wear and tear will increase in the same manner as for the general housing stock described above. In addition, indoor environments as well as precious objects and artefacts stored in this type of buildings may be affected, as for instance many churches and castles are not heated (SOU 2007:60, p 336). Degradation processes are thus accelerated, which will bring increased maintenance costs in the future. Moreover General wear and tear will increase in the same manner as for the general housing stock described above. In addition, indoor environments as well as precious objects and artefacts stored in this type of buildings may be affected, as for instance many churches and castles are not heated (SOU 2007:60, p 336). Degradation processes are thus accelerated, which will bring increased maintenance costs in the future., culturally important environments and areas may be

affected by climate adaptation and protective measures, for instance embankments (Länsstyrelserna, 2012 p 23).

7 Conclusion

8 References

Baltic Marine Environment Protection Commission (n.y.). *Sweden.* https://helcom.fi/about-us/contracting-parties/sweden/ [retrieved 17 May 2021]

Blekinge Arkipelag (n.y.). *Höga natur- och kulturvärden i biosfärområdet.* https://blekingearkipelag.se/v%C3%A5rt-biosf%C3%A4romr%C3%A5de/natur-kultur [retrieved 18 May 2021]

Boverket (January 2006). *Vad händer med kusten? Erfarenheter från kommunal och regional planering samt EU-projekt i Sveriges kustområden.* https://www.boverket.se/globalassets/publikationer/dokument/2006/vad_hander_med_kusten.pdf [retrieved 19 May 2021]

Boverket (December 2013). Tillståndet i den byggda miljön. https://www.boverket.se/globalassets/publikationer/dokument/2013/tillstandet-i-den-byggda-miljon.pdf [retrieved 19 May 2021]

Boverket (1 April 2020a). *Klimatförändringar.* https://www.boverket.se/sv/PBL-kunskapsbanken/planering/oversiktsplan/allmanna-intressen/hav/klimat/ [retrieved 6 May 2021]

Boverket (1 April 2020b). *Översiktsplanering vid kust och hav.* https://www.boverket.se/sv/PBL-kunskapsbanken/planering/oversiktsplan/allmanna-intressen/hav/ [retrieved 19 May 2021]

Boverket (1 April 2020c). *Besöksnäring – turism, camping och fisketurism.* https://www.boverket.se/sv/PBL-kunskapsbanken/planering/oversiktsplan/allmanna-intressen/hav/maritima-naringar/besoksnaring/ [retrieved 19 May 2021]

Boverket (1 April 2020d). Vattenbruk. https://www.boverket.se/sv/PBL-kunskapsbanken/planering/oversiktsplan/allmanna-intressen/hav/maritima-naringar/vattenbruk/ [retrieved 19 May 2021]

Boverket (22 December 2020). Kusterosion. https://www.boverket.se/sv/PBL-kunskapsbanken/planering/detaljplan/lansstyrelsens-tillsyn/tillsynsvagledning_naturolyckor/sakerhetsfragor/kusterosion/ [retrieved 8 May 2020)

Boverket (29 December 2020). *Regional fysisk planering.* https://www.boverket.se/sv/PBL-kunskapsbanken/planering/regionplan/ [retrieved 9 May 2021]

Centrum för Arbets- och Miljömedicin Region Stockholm (2020). *Ett faktablad from Centrum för Arbets- och Miljömedicin 2020 – Klimatförändring och hälsa.* http://dok.slso.sll.se/CAMM/Faktablad/Faktablad_klimat_och_halsa_webb_tg.pdf [retrieved 25 May 2021]

Havet.nu (8 April 2021). *Fakta om Bottniska viken.* https://www.havet.nu/-bottniska-viken [retrieved 17 May 2021]

Havet.nu (19 April 2021). *Fakta om Västerhavet.* https://www.havet.nu/vasterhavet [retrieved 17 May 2021]

Havet.nu (11 May 2021). *Fakta om Egentliga Östersjön.* Havet.nu/egentliga-ostersjon [retrieved 17 May 2021]

Havs och Vattenmyndigheten (3 March 2017). *Klimat.* https://www.havochvatten.se/miljopaverkan-och-atgarder/miljopaverkan/klimat.html#h-Hurforandrasklimatet [retrieved 6 May 2021]

Höga Kusten (n.y.). *Norrlandskusten.* https://www.xn—hga-kusten-ecb.se/sevardheter/norrlandskusten/ [retrieved 18 May 2021]

Klimatanpassning.se (20 August 2018). *Skydd av stränder i Ystad.* http://klimatanpassning.se/exempel/skydd-av-strander-i-ystad-1.80193 [retrieved 9 May 2021]

Klimatanpassning.se (3 November 2020). *Samhällsplanering.* http://klimatanpassning.se/hur-samhallet-paverkas/samhallsplanering/samhallsplanering-1.21499 [retrieved 9 May 2021]

Klimatanpassning.se (12 November 2019a). *Algblomning.* http://klimatanpassning.se/hur-samhallet-paverkas/naturmiljo-och-ekosystem/algblomning-1.151155 [33retrieved 8 May 2021]

Klimatanpassning.se (12 November 2019b). *Fysisk planering.* http://klimatanpassning.se/hur-samhallet-paverkas/samhallsplanering/fysisk-planering-och-bebyggelse-1.22566 [retrieved 9 May 2021]

Livsmedelsverket (21 January 2021). *Konsekvenser av ett förändrat klimat.* https://www.livsmedelsverket.se/produktion-handel—kontroll/dricksvattenproduktion/kaskad-handbok-for-klimatanpassning_dricksvattenproduktion/konsekvenser_av_ett_forandrat_klimat?AspxAutoDetectCookieSupport=1 [retrieved 5 May 2021]

Klimatanpassning.se (9 March 2021). *Brand. https://www.klimatanpassning.se/hur-klimatet-forandras/klimateffekter/brand-1.21286* [retrieved 5 May 2021]

Kramfors Kommun (7 January 2021). *Världsarvet Höga Kusten.* https://kramfors.se/se—gora/visit-kramfors/varldsarvet-hoga-kusten.html [retrieved 18 May 2021]

Lantmäteriet (n.y.). *Check out the beach with Lantmäteriet.* https://www.lantmateriet.se/en/about-lantmateriet/school-staff/geoskolan/grundskolan/koll-pa-stranden-med-lantmateriet/ [retrieved 18 May 2021]

Länsstyrelsen i Skåne Län (2011). Klimatanpassningsatlas för Skåne. https://www.lansstyrelsen.se/download/18.2e0f9f621636c84402730ead/1528811177641/LSTM_2011_Klimatanpassningsatlas_for_Skane.pdf [retrieved 25 May 2021].

Länsstyrelsen Skåne (n.y.) *Kustens Landskap.* https://www.lansstyrelsen.se/skane/besoksmal/kulturmiljoprogram/skanes-historia-och-utveckling/kustens-landskap.html [retrieved 18 May 2021]

Länsstyrelsen Stockholm (25 October 2017). *Skärgårdsfakta.* https://www.lansstyrelsen.se/download/18.1dfa69ad1630328ad7c89d0e/1548083610749/Fakta%202017-13%20Sk%C3%A4rg%C3%A5rdsfakta%20grafiska%20kartor.pdf [retrieved 18 May 2021]

Länsstyrelserna (2012). *Klimatanpassning I fysisk planering – Vägledning från länsstyrelserna.* Taberg Media Group

Malmberg Persson, Kärstin, Johan Nyberg, Jonas Ising and Lars Rodhe (2016). *Skånes känsliga stränder – Erosionsförhållanden och geologi för samhällsplanering.* SGU-rapport 2016:17

Mobjörk, Malin (2011). *Svensk krisberedskap och klimatförändringarnas indirekta effekter: Betydelsen av en bred framtidsinriktad analys.* Användarrapport, September 2011. Totalförsvarets Forskningsinstitut,

Nationalencyklopedin (n.y.). *Bohuslän.* https://www.ne.se/uppslagsverk/encyklopedi/l%C3%A5ng/bohusl%C3%A4n [retrieved 24 May 2021]

Naturvårdsverket (17 February 2021). *Konsekvenser för naturmiljö och ekosystem.* http://www.naturvardsverket.se/Sa-mar-miljon/Klimat-och-luft/Klimat/Klimatet-i-

framtiden/Effekter-i-Sverige/Konsekvenser-for-naturmiljo-och-ekosystem/ [retrieved 5 May 2021]

Naturvårdsverket (19 February 2021). *Klimatet förändras i Sverige.* https://www.naturvardsverket.se/Sa-mar-miljon/Klimat-och-luft/Klimat/Klimatet-forandras/klimatet-forandras-i-Sverige/ [retrieved 5 May 2021)

Naturvårdsverket (31 March 2021). *Konsekvenser för teknisk infrastruktur.* https://www.naturvardsverket.se/Sa-mar-miljon/Klimat-och-luft/Klimat/Klimatet-i-framtiden/Effekter-i-Sverige/Konsekvenser-for-teknisk-infrastruktur/ [retrieved 5 May 2021]

Naturvårdsverket (15 April 2021). *Konsekvenser för den areella sektorn.* https://www.naturvardsverket.se/Sa-mar-miljon/Klimat-och-luft/Klimat/Klimatet-i-framtiden/Effekter-i-Sverige/Konsekvenser-for-den-areella-sektorn/ [retrieved 5 May 2021]

Naturvårdsverket (22 June 2020). *Effekter i Sverige.* https://www.naturvardsverket.se/Sa-mar-miljon/Klimat-och-luft/Klimat/Klimatet-i-framtiden/Effekter-i-Sverige/ [retrieved 5 May 2021]

Naturvårdsverket (27 October 2020). Konsekvenser för människors hälsa. http://www.naturvardsverket.se/Sa-mar-miljon/Klimat-och-luft/Klimat/Klimatet-i-framtiden/Effekter-i-Sverige/Halsan-och-klimatet/ [retrieved 5 May 2021]

Naturvårdsverket, (27 November 2020). *Miljöövervakningens programområde Kust och hav.* https://www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sverige/Miljoovervakning/Miljoovervakning/Kust-och-hav/ [retrieved 19 May 2021]

Region Skåne (8 December 2020). *Livsmedel och jordbruk.* https://utveckling.skane.se/utvecklingsomraden/miljo-och-klimat/livsmedel-och-jordbruk/ [retrieved 25 May 2021]

Regionfakta (n.y. a). *Gotlands län – Ett urval av statistiken – snabbt och enkelt om regionen.* https://www.regionfakta.com/Gotlands-lan/ [retrieved 18 May 2021]

Regionfakta (n.y. b) *Gotlands län – Miljö.* https://www.regionfakta.com/gotlands-lan/miljo/ [retrieved 18 May 2021]

SFS 1998:808 *Miljöbalk*

SFS 2020:900 *Plan- och Bygglag*

Skansen (n.y.). *The Baltic Sea's Ecosystem.* https://www.skansen.se/en/%C3%B6stersj%C3%B6ns-biotop [retrieved 17 May 2021]

Skärgårdsstiftelsen (n.y.). *Vad är Stockholms skärgård?* https://skargardsstiftelsen.se/lattlast/vad-ar-stockholms-skargard/ [retrieved 18 May 2021]

SMHI (27 May 2020). *Hur förändras havsisen?* https://www.smhi.se/kunskapsbanken/klimat/klimateffekter-i-havet/hur-forandras-havsisen-1.28291 [retrieved 8 May 2021]

SOU 2007:60. *Sverige inför klimatförändringarna – Hot och möjligheter*

Statistsiska Centralbyrån (19 October 2011). *Bebyggelsepåverkad kust och strand.* https://www.scb.se/contentassets/e064a45b66a24f5d8d497fe5465ebd39/mi0807_2010a01_sm_mi50sm1102.pdf [retrieved 18 May 2021]

Statistiska Centralbyrån (8 December 2014). *Flest öar finns i Norrbotten.* https://www.scb.se/hitta-statistik/statistik-efter-amne/miljo/markanvandning/strandnara-markanvandning/pong/statistiknyhet/kust-strander-och-oar-2013/ [retrieved 18 May 2021]

Statistiska Centralbyrån (15 October 2020). *Marken i Sverige.* https://www.scb.se/hitta-statistik/sverige-i-siffror/miljo/marken-i-sverige/ [retrieved 8 May 2021]

Statistiska Centralbyrån (31 December 2020). *Folkmängd, topp 50.* https://www.scb.se/hitta-statistik/statistik-efter-amne/befolkning/befolkningens-sammansattning/befolkningsstatistik/pong/tabell-och-diagram/topplistor-kommuner/folkmangd-topp-50/ [retrieved 24 May 2021]

Statistiska Centralbyrån (12 May 2021). *Folkmängd i riket, län och kommuner 31 mars 2020 och befolkningsförändringar 1 januari – 31 mars 2020. Totalt.* https://www.scb.se/hitta-statistik/statistik-efter-amne/befolkning/befolkningens-sammansattning/befolkningsstatistik/pong/tabell-och-diagram/kvartals—och-halvarsstatistik—kommun-lan-och-riket/kvartal-1-2020/ [retrieved 17 May 2021]

Stockholm Archipelago (n.y.). *Welcome to the archipelago!.* https://www.stockholmarchipelago.se/en/ [retrieved 17 May 2021]

Svenska Kalkföreningen (2020). *Produkter. https://kalkforeningen.se/produkter/ [retrieved 7 May 2021]*

Sveriges Geologiska Undersökning (17 January 2018). *Klimatanpassning grundvatten.* https://www.sgu.se/grundvatten/klimatanpassning-grundvatten/ [retrieved 25 May 2021]

Sveriges Geologiska Undersökning (7 April 2020). *Stranderosion längs Skånes och Hallands kust.* https://www.sgu.se/samhallsplanering/risker/stranderosion/stranderosion-langs-skanes-kust/ [retrieved 6 May 2021]

Sveriges Vattenmiljö (n.y. a). *Klimat*. https://www.sverigesvattenmiljo.se/sa-mar-vara-vatten/2019/sammanfattningar/85/0/5#tillstand [retrieved 5 May 2021]

Sveriges Vattenmiljö (n.y. b). *Kust och öppet hav*. https://www.sverigesvattenmiljo.se/undersoka-vattenmiljo/kust-och-oppet-hav [retrieved 17 May 2021]

Sveriges Vattenmiljö (n.y. c). *Skagerrak.* https://www.sverigesvattenmiljo.se/undersoka-vattenmiljo/skagerrak [retrieved 24 May 2021]

Visby Handelstorg (n.y.) *Allt du behöver veta om Gotland.* http://www.visbyhandelstorg.se/ [retrieved 18 May 2021]

Världsnaturfonden (u.å.). *Klimatförändringar i Sverige.* https://www.wwf.se/klimat/klimatforandringar-i-sverige/ [retrieved 5 May 2021]

Ölands Turism (n.y.). *Om Öland.* http://www.olandsturism.se/AboutOland.aspx [retrieved 18 May 2021]

Ölands Turistbyrå (n.y.). *Kort fakta om Öland.* https://www.oland.se/sv/fakta [retrieved 18 May 2021]