Resilient Waterscapes in Genoa

From the Sturla Stream to the Ligurian Sea

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Index

Abstract

"Resilient Waterscapes in Genoa: from the Sturla Stream to the Ligurian Sea" is a proposal that seeks interventions that help reduce five challenges individuated within the stream landscape and the sea, where Posidonia oceanica has been decreasing.

The main challenges that face these interconnected systems are 1) the rising sea levels and the risk of flooding in rivers; 2) erosion and sedimentation of the stream and coastline; 3) urbanization and water pollution; 4) fires near water bodies, and 5) loss of biodiversity.

These challenges affect the quality of the uphill landscape and the subsequent one downhill, the sea, as both are part of a larger system connected through water. For this reason, the proposed interventions begin along the Sturla stream and end in the sea by addressing the problem of the decline of Posidonia oceanica, an important plant for its role against climate change, the protection of biodiversity, and the coast.

Therefore, some nature-based solutions (NBS) are proposed along the watercourse as three specific intervention points: Resilient Flooding Park-Resilient Cultivated Area, Interactive Stream Leisure Space, and Posidonia Modules at sea. NBS and Posidonia repopulation are mechanisms that help to address the five challenges mentioned above. The repopulation of Posidonia will be one of the steps to improve the ecological quality of this environment, at the same time creating people´s awareness and reinforcing the identity of the landscape.

The design proposal aims both to improve the environmental situation and the social conditions of the inhabitants of the Sturla, through interventions that allow the contemplation of the landscape and the development of activities of benefit to the community. Indeed, the proposal encourages both more resilient waterscapes and public uses.

Abstract in Italiano

"Resilient Waterscapes a Genova: dal Torrente Sturla al Mar Ligure" propone una serie di interventi volti ad affrontare cinque questioni individuate come rilevanti nel contesto del paesaggio fluviale e del mare, dove la Posidonia oceanica sta diminuendo.

Le principali questioni individuate rispetto a questi sistemi interconnessi sono: 1) l'innalzamento del livello del mare e il rischio di esondazione del fiume; 2) erosione e sedimentazione ; 3) urbanizzazione e inquinamento delle acque; 4) incendi in prossimità di corpi idrici; 5) perdita di biodiversità.

Questi problemi influenzano sia la qualità del paesaggio collinare sia quello a quota del livello del mare, entrambi parte di un sistema più grande collegato all'acqua. Per questo motivo, l'intervento inizia lungo il torrente Sturla e si conclude in mare, dove affronta il problema del declino della Posidonia oceanica, una pianta importante per il suo ruolo contro il cambiamento climatico, la protezione della biodiversità e della costa.

Alcune soluzioni basate sulla natura (NBS) sono proposte lungo il corso d'acqua: Resilient Flooding Park-Resilient Cultivated Area, Interactive Stream Leisure Space e Posidonia Modules in mare. NBS e il ripopolamento di Posidonia sono strategie proposte per affrontare le cinque questioni problematiche individuate. L'intervento relativo alla Posidonia sarà uno dei passi per migliorare la qualità ambientale di questi luoghi, stimolare al contempo consapevolezza nelle persone e rafforzare l'identità del paesaggio.

La proposta progettuale ambisce sia a migliorare la condizione ambientale sia quella degli abitanti, attraverso interventi che consentano la contemplazione del paesaggio e lo sviluppo di attività pensate per la comunità. La proposta incoraggia infatti sia Waterscapes più resilienti sia l'uso pubblico degli spazi.

Introduction

The past of Genoa has been characterized by a defensive landscape, represented by the walls, forts, infrastructure along the coast from medieval times to air-raid shelters from WWII. The hazards during those days were different from our present. It was a fight against human enemies and against some natural forces. Nevertheless, the question is: What is happening nowadays?

In the Anthropocene epoch we are currently living in, Genoa presents 5 important challenges: sea level rise and flooding rivers risk as consequence of the general changes in temperatures due to climate change and the covering practices that reduce the space for river flow, erosion/ sedimentation of rivers and coast line due to vegetation removal and increase in urbanization along watercourses,water pollution in rivers and sea as a result of industrial, commercial and residential land uses, fires in forested areas affecting aquatic ecosystems (another result of climate change) and finally, but not least, loss of biodiversity as result of the 4 previous problems.

These challenges have an important connection with the social and economic aspects of the city. Many commercial, industrial, touristic activities and housing development have affected the environment.The deterioration of this one produces also socio-economical problems, such as loss or damage of public infrastructure and private properties, forced migration, strong investments trying to find new fresh water sources or buying equipment to treat it, risks of loss human lifes, health problems and destruction of ecosystems services that are part of the cultural and economical realm of the city.

In 1950, 70% of the global population lived in rural areas, but the predictions for 2050 say that almost 70% of the world' s population will live in urban areas (United Nations.Department of Economic and Social Affairs, Population Division World, 2019).Moreover, 90% of the cities are coastal cities (Mancuso, 2020). Therefore, if we think about this data and the future of Genoa, it is clear the necessity of landscape architecture interventions according to this forecast.
We cannot speak of a 100% natural environment surrounding the city of Genova. However, there is an urban ecology, where marine and terrestrial ecosystems interact with the city fabric.

The proposal is oriented to transform the former idea of defense into a new strategy: resilience.This capacity of facing the challenges and coming back to the original state, has been focused on an important landscape: the waterscapes of Genoa, specifically the Sturla stream and the Ligurian sea area where this watercourse flows into.The 5 challenges can be addressed from specific points within these aquatic landscapes, where some nature based solutions (NBS) allow a better resilience to the impact of climate change and other human hazards.

The nature based solutions will be oriented on a major player: Posidonea oceanica.It represents an important allied in order to give a more resilient reaction to the current 5 challenges. Nevertheless, this main actor needs help in some stages before the sea, it means in specific points along the stream.Through an analisis of the site, those critical points will be identified and a landscape design proposal will provide possible interventions, becoming more resilient waterscapes for a better city future.

Genoa

How is the city?

Fig.1. Own photo. View of Genoa from Monte Moro.

Brief Introduction to Genoa

Genoa is a port city and the capital of the Ligurian region, in northwestern Italy. It is known for its central role in maritime trade several centuries ago, being one of most important way of communication between the industrial and commercial systems of north Italy and central Europe with the south Mediterranean and north Africa countries.

Genoa was one of the main centers of a civilization oriented to the sea transportation. Many landscape artists, such as Canaletto, Van Wittel, Massys, Vernet, Turner, Lorrain, Corot, were inspired by the natural landscape condition of its port and the complexity of its infrastructure, the maritime means of transportation movement and the richness of the buildings dedicated to the mercantile and financial activities. The city was described taking into consideration the beauty of its gardens surrounded by the walls and the nitide functionality of the port bounded by the urban. (Poleggi & Cevini, 1981)

The port is characterized for being surrounded by a mountainous land which approach very close to the sea. Its extension is over about 20 km of coast from Voltri to Nervi and covers 5000000 m2 of marine surface, where the water depth varies from 9 to 15 meters. Besides, marine activities of Genoa port develop about 47 km of length, 30 of which consist of modern quays, equipped to receive more than 200 ships of different dimensions.(ECO-information in European ports, 1999)
Genoa is an important city characterized for a high industrialization, important trading and tourist activities and high density in the urban area. All these features produce a high impact in terms of environmental and socio-economical aspects.

Regarding the specific site of the Resilient Waterscapes in Genoa proposal, it will be focused along the Sturla Stream and the area of the Ligurian Sea where this watercourse flows into.

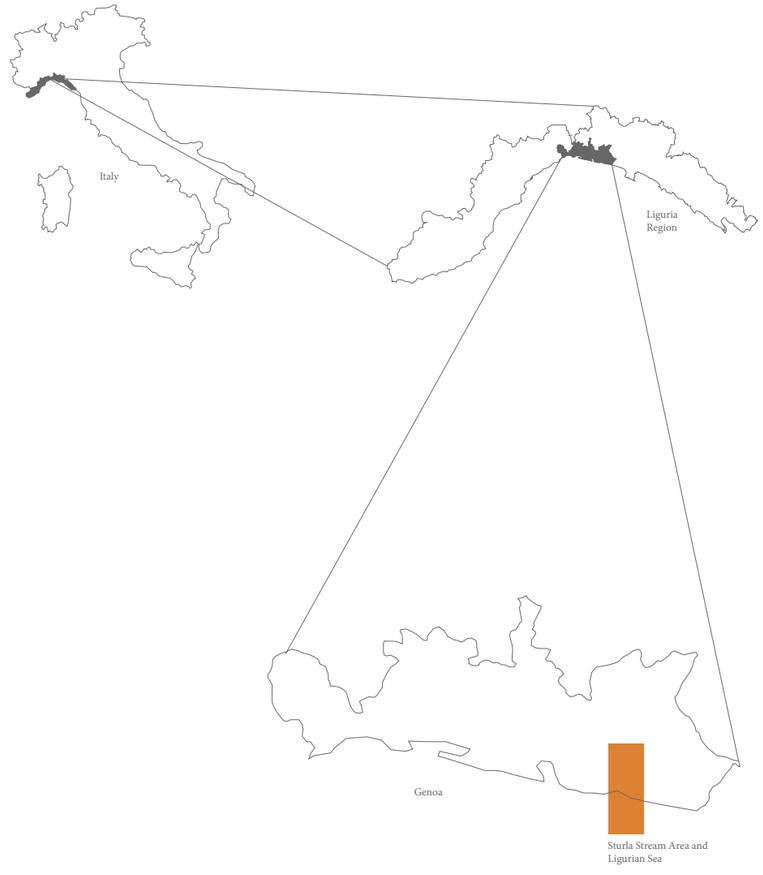


Fig.2. Location of the Study Area: Sturla Stream area and Ligurian Sea, Comune di Genoa, Liguria Region, Italy.

From Defensive to Resilient

What happened in the past and what happens today?

From medieval times until the Second World War, Genoa could be characterized for being more a defensive than relient city. Nevertheless, it is not possible to ensure how much resilient or not it was.

There is no certainty about the existence and material continuity of a real urban settlement before the medieval time, just some hipotesis from archeological excavations and latin citations from the Imperial age.But it is possible to mention that Genoa was allied to Rome during the Punic Wars (II century b.C) and it was the point of support for the troops that persued lugurian tribes almost during the entire century.Afterwards, during the Early Medieval Age,the original uncertain settlement was overlapped with a real urban plan defended by walls. Genoa was a fortified city, whose walls helped to control the entire coastal arc. (Poleggi & Cevini, 1981)

In fact, it is possible to observe those walls and its growing from the XIII to the XV century (Poleggi,1981), composed by fortifications (towers). Moreover, maritime and port works, such as pier, dock, arsenal and mooring bridges were incorporated.During the XVI century more walls were built, but mainly along the coast line. It is worth adding that the construction of infrastructure in the sea was product of a defense action against natural events, for instance the construction of Molo Nuovo and Le Mure Nuove, after the catastrophe of "libecciata"[1] occurred in 1613 and many others during 40 years before. In 1636, after many violent events and sunken boats, it was finally decided to resolve the defense problem of the port.

On the other hand, it is possible to include another more recent historical reference about defensive city: the Second World War.During this time several air-raid shelters were built for civilians and military purposes; their construction was conditioned by the geological and geomorphological features of Genoa. (Faccini,F. et al, 2019)
This brief description of the defensive landscape in Genoa has the purpose of asking some questions. We can see a landscape that was characterized by the wars in the past, but what is the war do we face today? What kind of hazards or challenges are affecting Genoa nowadays? How can these challenges be approached from a resilient strategy more than a defensive one? "Resilience represents the ability of an urban system to adapt to an external event and quickly return to normality"(Pirlone et al., 2020), therefore strategies that answer more properly this statement from the environmental and socio-economical point of view must be required.

The name of the city comes from the mythological reference of the god Janus (Giano), who looks to the past and the future. Similarly, those questions seek to reinterpret the defense against the threats that were lived in the past and transform it into a future of resilience to the threats in the present, such as sea level rise due to climate change, urbanization and water pollution, erosion and sedimentation processes, fires nearby water bodies and biodiversity loss, all of them linked to socio - economical repercussions.

Fig.3. Furrtenbach illustration that describes the terrible effects of the libecciata, November 11th 1613 in the port of Genoa. (Poleggi & Cevini, 1981)

1 Gust, gust of libeccio, or succession of gusts of libeccio; also, the totality of the phenomena and the harmful effects (swells) that accompany the violent phases of the wind of libeccio, which are subject of the Italian Tyrrhenian coasts. Dictionary Treccani https://www.treccani.it/vocabolario/libecciata/

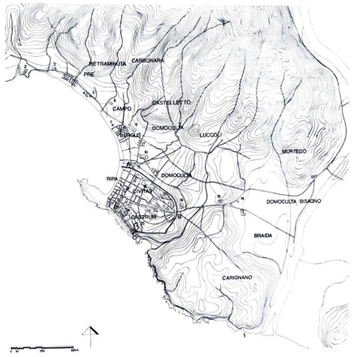


Fig.4. Port development XI century

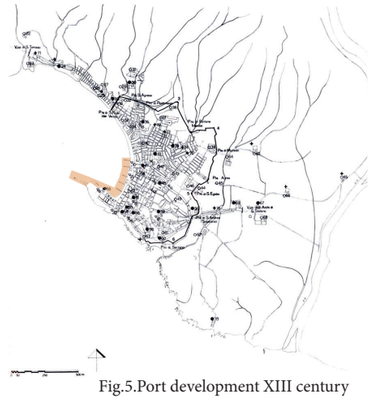


Fig.5.Port development XIII century

Fig.6. Port development XV century

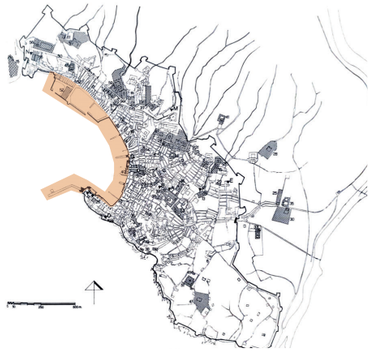


Fig.7.Port development XVI century

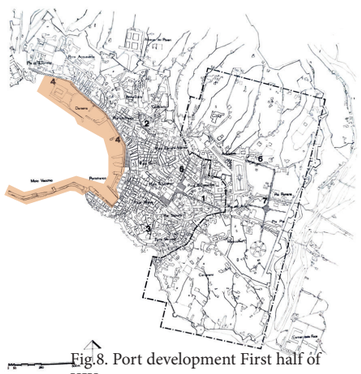


Fig.8. Port development First half of XIX century

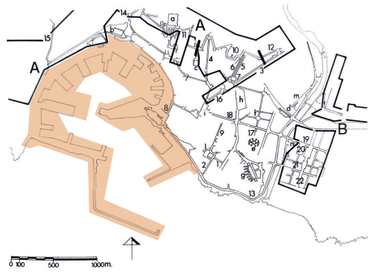


Fig.9. Port development Second half of XIX century

Defensive examples in the past

Regarding the port development, from figure 4 to figure 10 (Poleggi & Cevini, 1981) it is possible to observe the increase of maritime and port works along the centuries. Some of this infrastructure was built with a defensive function, for instance the Molo (pier) that is a kind of defensive wall from the water action and the different Darsenas (docks), that are sheltered areas from marine currents. Moreover, an example of defensive infrastructure is the "mura di mare" or sea walls (fig.13)

Nevertheless, this infrastructure was concentrated in the port area, where the urban development was carried out. Between the old and the new walls (urban development from the 1800's) there was an area cleared from constructions.

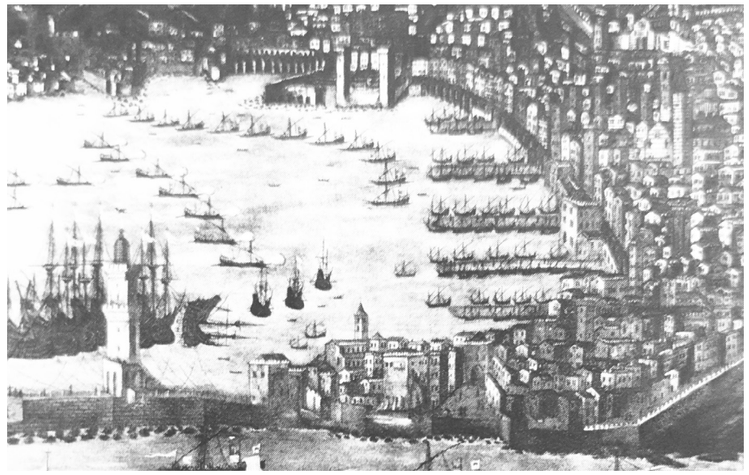


Fig.10. The harbour occupied approximately a third of the genoese bay.Until the construction of the New Pier, it was subordinate to the angry blows of the libeccio, reducing the area of safety (Poleggi & Cevini, 1981)

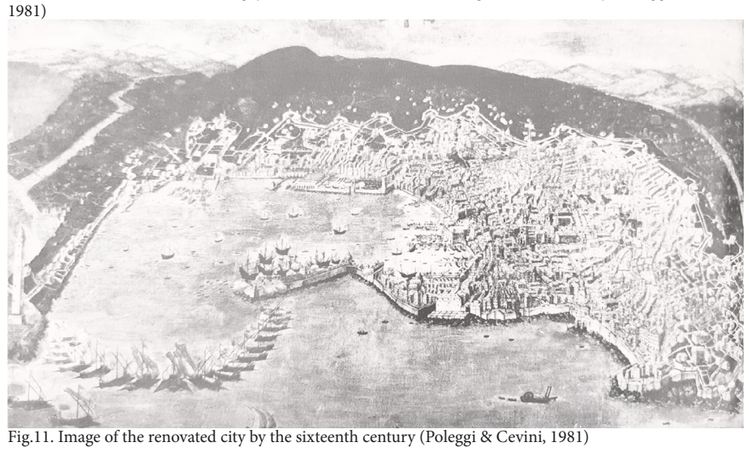


Fig.11. Image of the renovated city by the sixteenth century (Poleggi & Cevini, 1981)

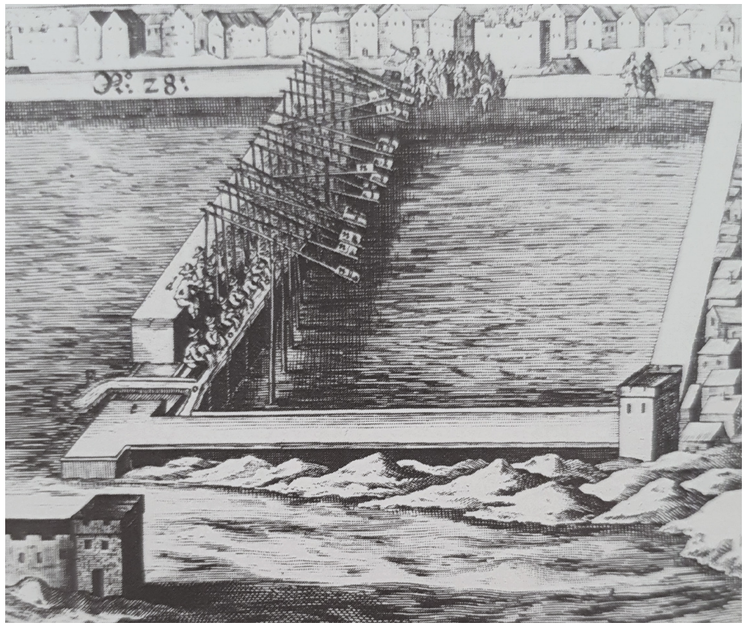


Fig.12. Description of a "passionata" for tidying up the depths of the dock, Joseph Furrtenbach, Newes Itinerarium cit, 1627.(Poleggi & Cevini, 1981)

Fig.13. View of the buildings of underpasses with bridges Reale,Spinola e Calvi, leaning against the "sea walls". It represents an example of defensive infrastructure (Poleggi & Cevini, 1981)

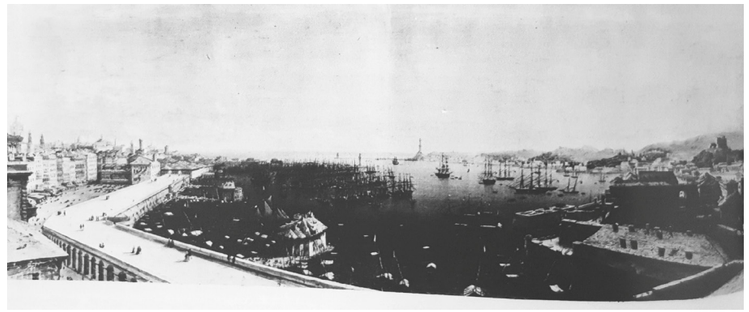


Fig.14. Marble terraces built after 1835 and demolished around 1880 during the renovation and expansion of the port (Poleggi & Cevini, 1981)

Fig.15.Study site: Sturla Stream area and Ligurian Sea, about 1820 (Poleggi & Cevini, 1981)

Therefore, the surroundings of the port of Genoa, such as the Sturla area, located outside of the walls from the 1500's, was a desolated landscape, formed by fishing villages.(see fig.15)

In the pictures shown here, it is possible to observe a different kind of relationship between the urban (see fig.10-14) and rural (see fig.16-20) with the sea. The port of Genoa presents a more sharp edge due to the features of maritime works,on the other hand, the more rural sites have a softer border due to the lack or minimal presence of infrastructure.

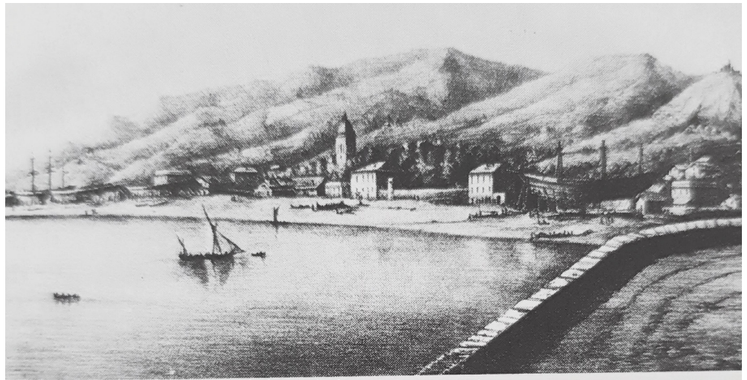


Fig.16. Example of relationship with the sea.(Poleggi & Cevini, 1981)

Fig.17. Example of relationship with the sea.(Poleggi & Cevini, 1981)

Fig.18. Example of relationship with the sea.(Poleggi & Cevini, 1981)

Fig.19 -20. Example of relationship with the sea.(Poleggi & Cevini, 1981)

However,the areas with more interventions within the sea (urbanization of the sea) have created a kind of sheltering space, almost an extension of the land activities into the water.Meanwhile areas without strong interventions reflect a more defined limit, the wild sea keeps its nature and touches the coast without defensive works that stops its force.

Defensive examples in the present

Nowadays, as stated by the Piano Urbanistico di Genova (PUC - *Sistema Portuale e Litorale*) there is a concern about the coastal defense and beach replenishment. In Liguria only a quarter of the coast is represented by a beach coast, representing 94 km out of 359 km.

As a result, more and more massive measures are being taken to maintain the stock of this resource. Besides, taking into consideration the importance that bathing tourism has for the Liguria, it brings out the necessity of addressing intervention methodologies by integrating the original concept of defense of the inhabited areas through interventions aimed to protect against marine aggression. The Plan proposed to create favor conditions in order to allow a more natural evolution of the coast line and to guarantee stability through a complex of organic interventions based on two fundamental components: the arrangement of basins and river shafts to facilitate the restoration of areas with greater solid transportation of sediments to the sea as well as a system of defensive works and replenishment for unitary stretches of the coast.

LEGEND

MAIN WATER BODIES

Sea

Rivers

DEFENSIVE INFRASTRUCTURE

Existing coastal defensive infrastructure

Projected coastal defensive infrastructure

Main defensive harbour infrastructure

0 1 2 3 km

Scale 1:25000

Map 1. Existing and projected coastal defensive infrastructure and main defensive habour infrastructure. Source: Geoportale Regione Liguria Data.

A possible Resilient Landscape

Waterscapes, why are they important?

Landscape must be more than a background, landscape must be action. As Charles Waldheim mentions in The Landscape Urbanism Reader *"landscape has become both the lens through which the contemporary city is represented and the medium through which it is constructed"*.

Nowadays, this statement must be stronger due to the challenges that the Anthropocene represents to us. According to Kate Orff in Towards Urban Ecology, the botanist and ecologist Eugene Stoermer coined this term Anthropocene to explain our current planetary epoch, that is characterized for different problems as climate change, loss of biodiversity, dissolution of social fabrics, as well as the human impact on sedimentary and geological processes.

In order to face these challenges, a new discipline has emerged as the new brick in urbanism: landscape instead of architecture. If we introduce ourselves into this field, a whole series of concepts emerge among the urban, ecology, sustainability and resilience. It is the search of the greatest possible balance between the human and non-human, the artificial and the natural.

It is here that concerns arise about how this way of integrating the landscape into the human-made world can in fact provide solutions to problems, eliminating or mitigating the consequences of our actions.

As J. Czerniak mentions *"to think about landscape is to think about site"*, not just a site with highly valued features but also contemporary challenges. The site of the present landscape architecture proposal is focused on the waterscapes of Genoa, giving importance to the seascape but also the direct influences of the sea: the rivers.

The aquatic landscapes or Waterscapes are often ignored, as they usually become something foreign to our condition as terrestrial beings. What happens along the waterways and within the sea it is often unknown, inaccessible.

Curiously, Genoa is a port city, meaning that the sea is one of its limits. But there is not only the sea, there are also rivers and streams that in their journey through the mountains and the city, they drag the human mistakes. What happens inland affects the sea and us as well.

This is the importance of waterscapes,they can be deteriorated by human actions but also they can affect human beings living near them.

After reflecting on what is a resilient landscape, the concern arises to analyze the main torrents and the Ligurian sea, understanding how this Anthropocene epoch has affected them and how they could respond and recover themselves, so that future generations can find a more sustainable model, integrating environmental, social and economic aspects within the city.

The aquatic landscape thus becomes the brick or constitutive piece of what could be named a new type of urbanism: the waterscape urbanism. Starting from this and how the city - in interaction with ecological concepts - becomes more resilient and eventually sustainable.

Urban use of the coastline

As specified by Piano Urbanistico Comunale di Genova (PUC - *Sistema Portuale e Litorale*), today the coastline has some areas that have been released from an exclusively economic exploitation connected to the harbour infrastructure, but it is not still a space where the citizens and tourists can approach the *"free access and transit to reach the foreshore of the area covered by the concession"*. Therefore, if we consider some economic sectors such as tourism, sport and leisure, entertainment, but also social health services, the tendency of the tourism market-bathing is to have more complex and articulated structures aimed to operate even outside the traditional bathing season.

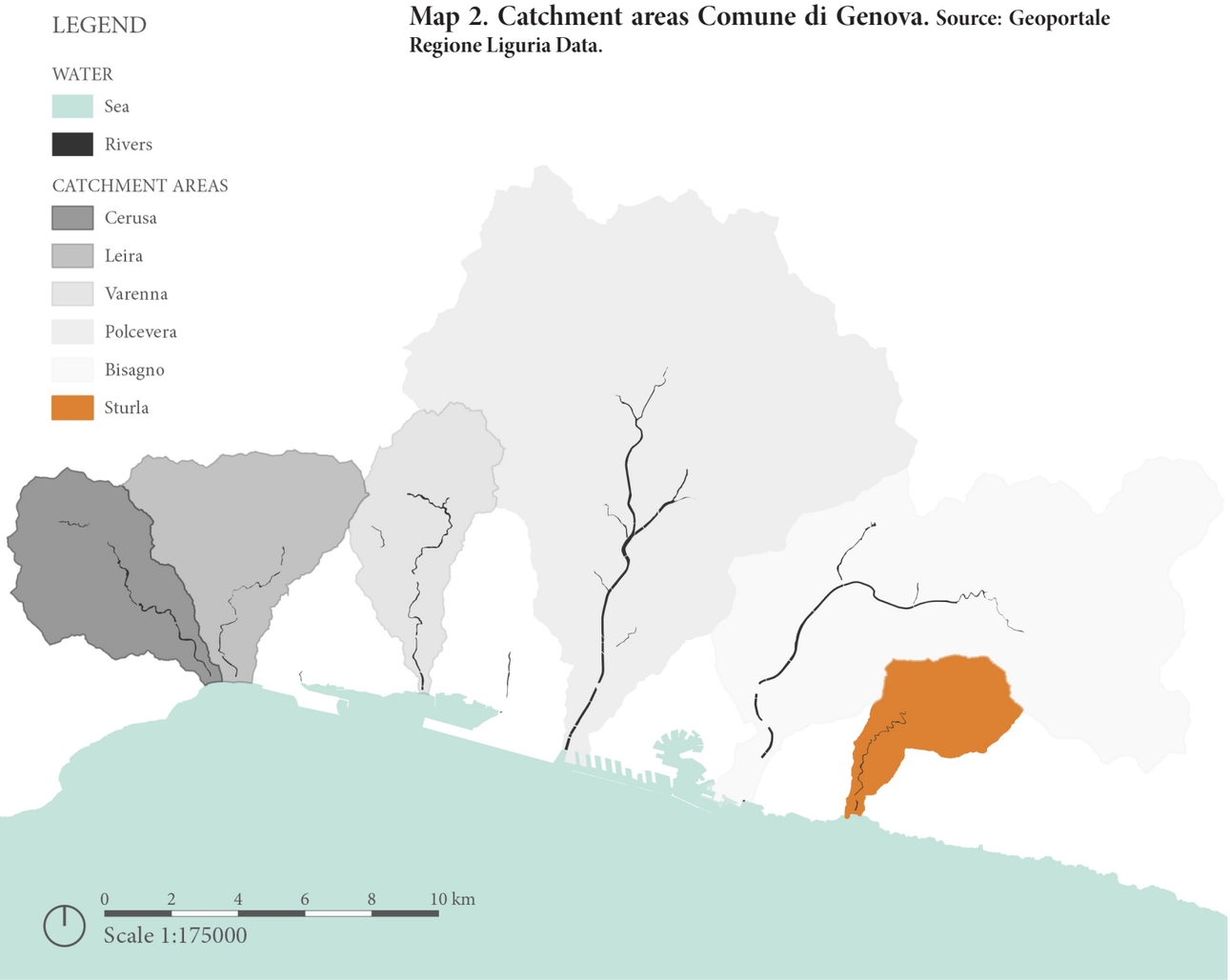
Sea resource can be used in many different ways, giving socio-economical and environmental value.

Setting aside the port infrastructure area normed by the Piano Regolatore Portuale (PRP), the rest of the coastline correspond to the *"Demanio Marittimo"* or maritime domain, which is managed by the Comune di Genova and whose destination is entrusted to the town-planning projections, oriented to urban uses.

According to the *Piano di Utilizzazione delle Aree Demaniali Marittime*, the general requirements to be observed in the maritime domain management are: free and public use, protection of the coastline from erosion, protection against hydrogeological risk and for the protected areas. On the other hand, the specific requirements are: recreational tourist uses, nautical leisure uses, productive activities, maritime works and replenishment.

Waterways in Genoa

As specified by the Piano Comunale di Emergenza Schema Operativo per Rischio Meteo-Idrogeologico, almost all the waterways that cross the territory of the Municipality of Genoa originate on the southern side of the Ligurian Apennines and



Map 2. Catchment areas Comune di Genova. Source: Geoportale Regione Liguria Data.

after a short route in a north-south direction lead into the Ligurian Sea.Overall, all basins have features of mountainous streams, with strong acclivity, a short distance between the watershed and the shore line, and the presence of narrow coastal plains, originated by the progradation of the torrential mouths, intensely urbanized and exposed to the risk of flooding.

The city's territory is affected by about 100 river basins with a generally small size: 44 of the 57 river basins have a surface area of less than 2 km2, 6 have a surface area between 2 and 10 km2 and 7 are larger than 10 km2.

There are the coastal basins of Polcevera and Bisagno, as well as a series of coastal basins in Ponente, Levante and Downtown. From the coastal basin of Levante, the most important rivers are the Sturla and Nervi. The catchment of the Sturla stream, which has has been selected as the intervention area, has an extension of 13 Km2 (see map 2, colored area in orange) and the length of the main watercourse is about 9 km, therefore it is a small basin, particularly acclive (classes of acclivities prevailing from 35 to 75%). [2]

2 Information from Piano Comunale di Emergenza Schema Operativo per Rischio Meteo-Idrogeologico, Comune di Genova. Direzione Corpo di Polizia Municipale Settore Protezione Civile e Comunicazione Operativa (2015)

Resilient Waterscape in Genoa

Sturla Stream and Ligurian Sea

Introduction

Sturla Stream is just a small catchment if we compare it to Polcevera or Bisagno ones, nevertheless this watercourse and the area of the Ligurian sea in which this stream flows into, represent a great oportunity in terms of environmental and socio-economical aspects.Why? Because in this area we can find the 5 challenges are affecting Genoa.

There are fires threatening some residential areas but also important ecological corridors characterized for a big variety of birds species, that could be affected by the urban fabric. There is water pollution due to waste discharges into the ocean but at the same time the presence of Posidonea oceanica prateries that have been fighting for surviving.There are sea level rise and flooding risk, and erosion/sedimentation problems.

The journey of Sturla Stream goes through a residential area and several services, such as health, recreational, sports and educational ones. Among the health services there is one with a very particular relationship with the sea: "Istituto Giannina Gaslini", a children´s hospital and center of medical research since 1938, the biggest hospital in the northern part of Italy. The closeness to the sea represents an oportunity in terms of the social impact it can have for patient 's health recovery. Children can look at the sea from their windows and this view and the proximity could be taken in benefit of this population. Moreover the Hospital carries out activities with children in order to give them a little piece of joy although their difficult circunstances, so these activities could be related to the posidonia regeneration project in the beach in front of the Hospital.

Other activities as for example: vegetable gardens, recreational-sports and educational centers could be linked to the nature based solutions along the stream and finally in the sea.

Description of the site

In the basin of the Sturla Stream, as specified by Piano di Bacino Stralcio per la tutela dal rischio idrogeologico (*Ambito 14 Torrente Sturla,2016*), despite the only 9 km of length there is a sharp transition from suburban areas with still rural characteristics to an area of high urbanization, which extends over the hills.In summary, we can distinguish:

- a purely urban area situated in the lower part of the basin.
- a middle part of the valley (narrow and very acclive) where there has been a strong anthropic action of deforestation, with the obvious consequences on soil conservation and stability.
-a high part of the valley where a lower acclivity, due to the geolithological-geomorphological characteristics, has allowed the establishment of agricultural, forestry and pastoral activities.

In accordance with the SWOT Analysis of Municipio IX Levante (PUC, *Partecipazione*), there are some strengths regarding the environment and human health topic in this site, due to the presence of physical and social characteristics. In fact, the site is a combination of hilly areas, sea- beaches, green spaces and a vulnerable population made up of elderly, children and disabled people. Nevertheless, the physical conditions could represent obstacles in certain situations, also they could be an opportunity, for instance through activities taking into consideration the sea (thalassotherapy).

The study site extends fromVernazzola beach, the "Fronte Mare di Sturla" and the Scoglio dei Mille (Quarto dei Mille).

According to the PUC (*Sistema portuale e litorale and Norme Livello Paesaggistico Puntuale Arco costiero di Riqualificazione*), in the Vernazzola area it is possible to find the presence of human settlements of fishermen and sailors (villages since the year 1000). The landscape and the architecture remained almost unchanged until the end of the nineteenth century. Buildings present the traditional materials, techniques and facades color choices from the Ligurian seaside villages.

Sturla is an ancient fishing village located on both sides and mouth of the stream Sturla. The landscape value of the places is constituted by the wide beach at the mouth of the Sturla torrent and by the historical residential area crowned by the promontories enclosing the arch, characterized by exceptional vegetation. Moreover, the coastal arc is characterized by a wide opening of the visual, giving panoramic views.

Regarding vegetation, the area is essentially devoid of prominent green while it is strongly present on the promontories of Vernazzola and Sturla. In particular the vegetation of the Gaslini Institute is a striking green frame.

From the Sturla beach,the Gaslini Institute and Quarto dei Mille (Monumento ai Mille), there is a landscape of exceptional value too. Elements of the natural and anthropic landscape (emerging rocks, vegetation of parks, villa gardens) in alternation with headlands and bays; the area presents numerous bathing establishments, now built on cliffs or on beaches. This recreational vocation is ancient: numerous villas testify that the area was a place of historical holiday for the Genoeses. There is the presence of shops, services, diving schools and restaurants, as well as villas and buildings of great beauty.

At Quarto ai Mille,in front of the rock from where Garibaldi left, there is the monument that commemorates the expedition, the work of the sculptor Eugenio Baroni.

Along the areas of Vernazzola beach, Sturla beach and the Scoglio dei Mille, there is an important element that indicates the environmental value of this arch: the Marine Site of Community Interest "Fondali da Boccadasse a Nervi", where the interest of the site is due to the presence of grasslands of Posidonia oceanica located partly on rock partly on "matte", interspersed with Coralligenous populations.

As stated by PTC della Costa (*Indicazioni generali per la riqualificazione del territorio, la valorizzazione del paesaggio costiero e la tutela dell'ambiente marino*),this area has a high landscape value and high social significance. The pressure of use of the entire city has involved a substantial privatization of the coast occupied by concessions of bathing establishments, associations, private individuals.The phenomenon, however, is not to be understood completely negatively, given the function of leisure and economical income that in fact represents, but it is still a feature that, together with the scarcity of bathing shoreline (both for the well-known phenomena of pollution, both for the morphology itself of the coast), reduces public access to the sea and pedestrian walkability along the coast.

Besides, the absence of a specific planning has generated the proliferation of artifacts, fences, defensive works often uncoordinated and harmful and against the aim of protecting the coastline (contributing to aggravate the erosion of the beaches themselves).

Current interventions

Regarding the PUC 2000 (*Stato di attuazione del PUC vigente*), the main interventions that have been planned in Sturla are the construction of a new road along the course of the Sturla river (district 69 aggregate A), in fact not realized, as well as a private enclosed parking under approval.

On the other hand, the interventions carried out during the period of operation of the PUC is the Area 69 B (bottom of the Stream Sturla). This intervention corresponds to the safety of the Sturla stream banks in this final part.

As we can see, interventions are not well articulated into a more sustainable proposal, rather than individual infrastructure works mainly related to vehicles and some attempts of water management improvements.

Challenges

from Sturla Stream to the Ligurian Sea

Challenges

Introduction and Interconnection

Five challenges have been identified in Genoa. These challenges are related to environmental problems, however, they are simultaneously linked to socio- economical problems too.

Challenges are as follow:

1- Sea level rise and flooding rivers risk
2- Erosion and Sedimentation of rivers and coastline
3- Urbanization and Water Pollution
4- Fires nearby water bodies
5- Loss of Biodiversity

Interconnections

The 5 challenges are interconnected and sometimes one of them could be the cause or effect from the others. Starting from the general statement of climate change, it is possible to identify the different links among challenges.

According to the AR6 Climate Change 2021:The Physical Science Basis (IPCC, 2021) the increases in greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities and since 2011, concentrations have continued to increase in the atmosphere.The greenhouse effect is an essential phenomenon for survival on Earth, however, its intensification causes several negative situations for our planet.

For example, each of the last four decades has been successively warmer than any decade that preceded it since 1850: *"the likely range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is likely that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C"* (IPCC, 2021). This incrementation in temperatures influences the global retreat of glaciers and the decrease in Artic sea ice area, as well as, the changes in the globally averaged precipitation over land (a faster rate of increase since the 1980s). Those situations are increasing at a time the global mean sea level.[3]

3 Global mean sea level increased by 0.20 [0.15 to 0.25] m between 1901 and 2018. The average rate of sea level rise was 1.3 [0.6 to 2.1] mm yr–1 between 1901 and 1971, increasing to 1.9 [0.8 to 2.9] mm yr–1 between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm yr–1 between 2006 and 2018 (high confidence). (IPCC, 2021)

Changes in precipitation also leads to flooding events. Sea level rise and flooding river risk involve forced migration and loss or damage of infrastructure and properties. Moreover, those changes in the sea and the rivers intensify the phenomenons of erosion and sedimentation, provoking again destruction of infrastructure, loss of private properties and reduction of coastal area.

Temperature and precipitation pattern alterations, can also cause fires events in forested areas nearby aquatic ecosystems. This challenge creates socio-economical challenges too, such as loss of human lifes and properties and infrastructure.

Regarding the closeness to aquatic bodies, the fire challenge can lead to another one: water pollution in rivers and sea, due to the fire byproducts that affect the chemistry of soils and eventually the water bodies. This pollution also can be produced by the industrial, commercial, touristic and residential land uses. The socio- economical challenge linked to this environmental problem is the destruction of fresh water sources needed for industries, commerce, housing and so on. It means more resources focused on getting clean water or more equipment and infrastructure for treat it.

Finally, but not least important is the loss of biodiversity, which is the result of all the challenges described before. In terms of socio-economical consequences, it is possible to mention the loss of quality in landscapes and quality of life, related to cultural ecosystem services. Besides, the detriment of ecosystem services of provisioning, regulating and supporting that have an impact on the economic income of the site.

I.IV. Challenges
What are the main problems in Genoa?

Environmental problems linked to Socio-economical ones

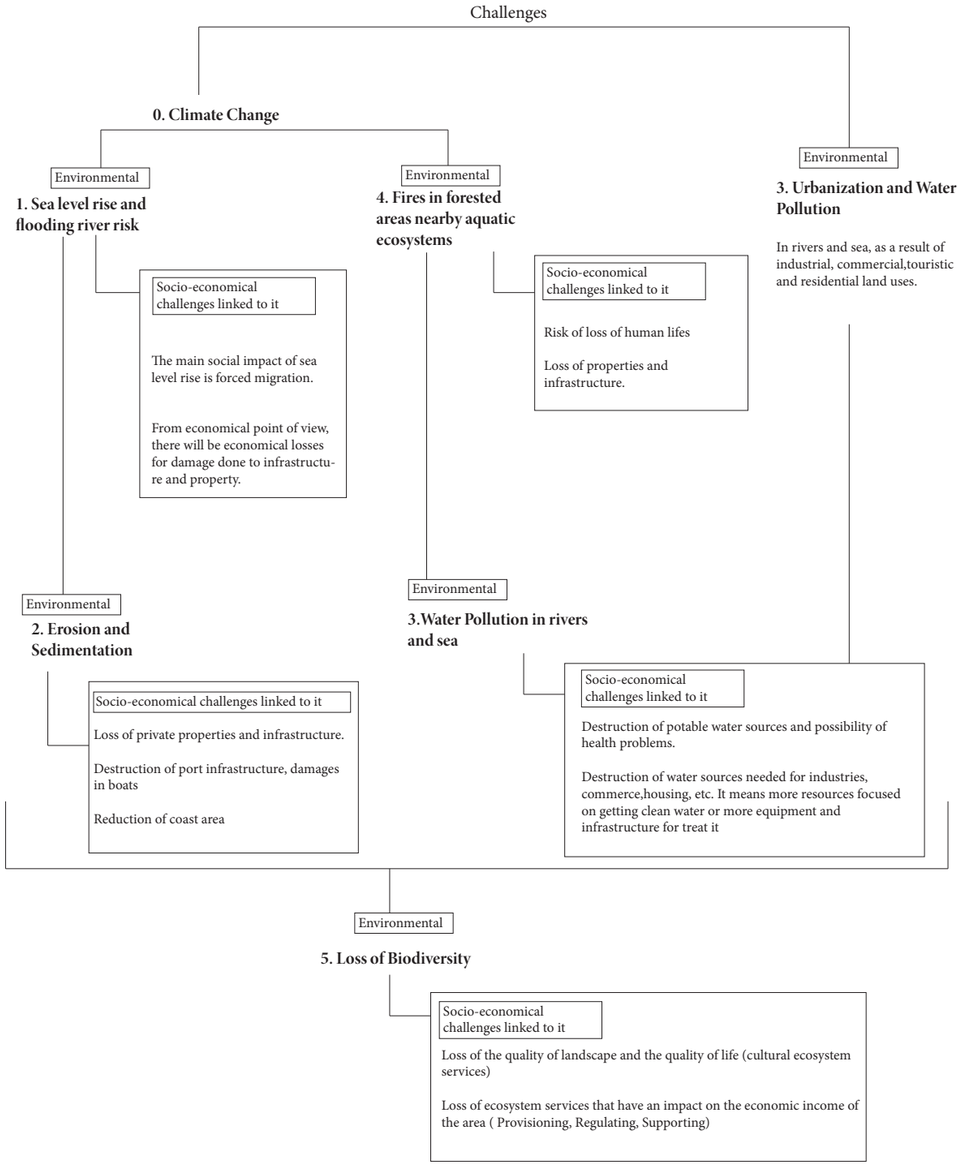


Fig.21. Diagram of Interconnection of Challenges. Own elaboration.

Challenge 1

Sea level rise and flooding rivers risk

Sea Level Rise

According to Hallegatte et al. (2013) *"climate change will lead to an increased risk of flooding and huge economic losses if countries do not invest in appropriate adaptation measures"*, this statement highlights the risk to coastal cities. Genoa represents a clear example of this risky situation.

The Piano Urbanistico Comunale di Genova (PUC) takes into consideration the Intergovernmental Panel on Climate Change (IPCC) and remarks how the ruinous fires, torrential rains, prolonged heatwave and thinning of the ice sheet would be the consequence of greenhouse gas concentration. Coastal areas, but also islands and whole archipelagos could disappear of the map due to the rise of the oceans and the melting of the ice. The dimension of the potential consequences will be combined with aggravating factors related to economic activities. The episodes of flooding could get worsen and multiply, disrupting the economy and the stability of the territory.

Regarding the Projected Sea- Level Rise information we can obtain from NASA, there are different Shared Socioeconomic Pathway (SSP) scenarios based on the assessment presented in the IPCC Sixth Assessment Report [4]. Those scenarios could be simplify as different levels of future greenhouse gas emissions: very low, low, intermediate, high and very high.

Depending on the different amount of emissions, temperature will vary and this variation also would signify a different sea level rise. In order to understand how the coast of Genoa could be affected by these temperature changes due to climate change, it is useful to show the Climate Central map, as a comparison of long-term sea level outcomes.This map uses localized sea level rise projections from Strauss et al. 2015, which builds on the projections of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013).

These projections forecast the long-term equilibrium sea level that will result from different amounts of global warming, but they do not predict when these sea levels will be reached, but diverse researches indicate that these sea levels could be realized between 200 and 2000 years from now. Despite of the several centuries they could take to arise, the carbon pollution choices during this century could commit us to them much sooner.

Nevertheless, these sea level forecasts according to global warming (Climate Central map) are still related to the temperature changes predicted for each SSP scenary according to NASA approximations.[5] Therefore, the maps shown in the next pages (see maps 3 to 6) are taking into consideration four different temperature increasings: 1,5 C, 2 C, 3C and 4 C. Those temperatures represent a synthesis of the different temperature variations we can experiment according to our carbon pollution choices.

It is possible to observe as temperature increases, the sea water gets more inland. At 1,5 C the water can reach 100 m inland from the coastline, at 2C it increases to 200 m, at 3 C it is possible to reach 300 m and at 4C it could be 450 m (all of them approximated average measures according to the distances in the maps). Indeed, the most affected areas from each temperature variation can reach from 1 to 2Km from the coastline.

Flooding rivers risk

On the other hand, the flooding rivers risk are linked again to the climate change because the amount of rain has been affected. Rains contribute in particular to characterise the climate of Genoa. In fact, the average annual totals and the monthly distribution of rains does not depart from the norm of the Mediterranean climates, but it has been possible to observe the presence of temporal episodes of great violence with extremely irregular rate.(PUC,*Clima e Microclima*).

During such events, the intensity of precipitation is always very noticeable: in case of heavy but short duration, local flooding may occur, if exceptional precipitation persists for several hours, the consequences on the city can be of much greater impact.

According to some data extracted from the PUC, the annual total of precipitation is equal to 1296 mm on average, the wettest month is October (222 mm), the driest July (27 mm). There is a total of 80 rainy days, with maximum autumn-spring (9 days) and minimum in July (3 days). (see fig.22)

[4] The scenarios are described in Cross-Chapter Box 1.4:
SSP1-1.9 holds warming to approximately 1.5°C above 1850-1900 in 2100 after slight overshoot (median) and implies net zero CO2 emissions around the middle of the century.
SSP1-2.6 stays below 2.0°C warming relative to 1850-1900 (median) with implied net zero emissions in the second half of the century.
SSP2-4.5 is approximately in line with the upper end of aggregate Nationally Determined Contribution emission levels by 2030. SR1.5 assessed temperature projections for NDCs to be between 2.7 and 3.4°C by 2100, corresponding to the upper half of projected warming under SSP2-4.5. New or updated NDCs by the end of 2020 did not significantly change the emissions projections up to 2030, although more countries adopted 2050 net zero targets in line with SSP1-1.9 or SSP1-2.6.
SSP2-4.5 scenario deviates mildly from a 'no-additional- climate-policy' reference scenario, resulting in a best-estimate warming around 2.7°C by the end of the 21st century relative to 1850-1900.
SSP3-7.0 is a medium to high reference scenario resulting from no additional climate policy under the SSP3 socioeconomic development narrative. SSP3-7.0 has particularly high non-CO2 emissions, including high aerosols emissions.
SSP5-8.5 is a high reference scenario with no additional climate policy. Emission levels as high as SSP5-8.5 are not obtained by Integrated Assessment Models (IAMs) under any of the SSPs other than the fossil fueled SSP5 socioeconomic development pathway.
https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool?psmsl_id=59

[5] Compared to 1850-1900, globally averaged surface air temperature over the period 2081–2100 is very likely (at least a 90% probability) to be higher by 1.0°C–1.8°C under SSP1-1.9, 1.3°C–2.4°C under SSP1-2.6, 2.1°C–3.5°C under SSP2-4.5, 2.8°C–4.6°C under SSP3-7.0, and 3.3°C–5.7°C under SSP5-8.5.

https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool?psmsl_id=59

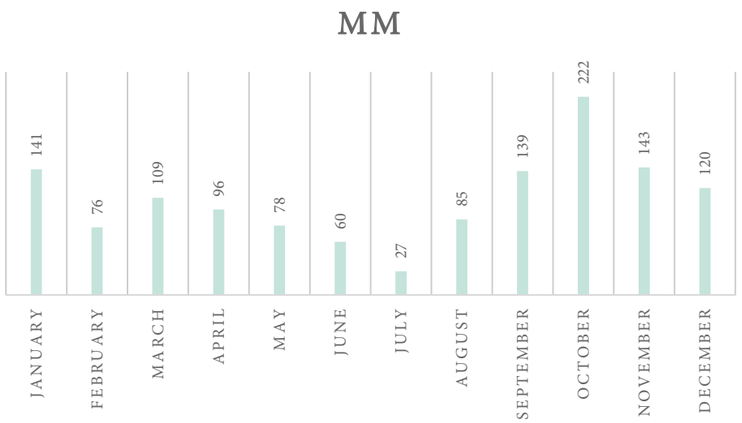


Fig.22. Precipitation in Genoa, amount of mm per month. Piano Urbanistico Comunale di Genova (PUC) Clima e Microclima.

Regarding the Piano di Bacino Stralcio per la tutela dal rischio idrogeologico (*Ambito 14, Torrente Sturla*), the Sturla River climate is characterized by a bimodal distribution of rainfall: in autumn a maximum amount (October about 180 mm) and secondary in spring (March 110 mm), very similar to the general data in Genoa . Besides, 64% of the annual rainfall is distributed on average in the winter months and autumn, often manifesting itself in the form of sharp rainfalls concentrated in autumn, a period in which the main and most dramatic floods have generally occurred.

Historically flooded areas

Still on the subject of flooding risk, it is important to show the historically flooded areas. This information has been obtained from the Piano di Bacino (*Ambito 14, Torrente Sturla*) and this one derives from the mapping reported in DGR No. 2615/98 and its subsequent changes, supplemented by numerous interviews with residents along the waterways.

The main problems that have been found, proceeding from upstream to downstream, are:

a. From **San Desiderio** to Nasche localities, there have been small localized floods, especially in structures inside the banks (mainly right bank) such as low floors of houses (which probably in the past had other uses), gardens and outbuildings.

b. From **Nasche** locality, the stream Sturla describes some meandering curves. In these meanders, internal areas have been subject of considerable floods. In particular the internal curve near the abandoned school of Nasche, where have been reported floods more than a meter height. Therefore, Nasche and also Moglie locality, are vulnerable areas,where the embankments are completely inadequate. Some houses overlook with windows directly on the riverbed.

c. In **Binella** locality, although it has been recently reported limited flooding events, in many places the water has reached the limit of the containment structures,so it highlights the existence of critical conditions anyway.Moreover, the crossbar made for crossing the sewerage constitutes a real barrier to the riverbed, its presence has caused a significant rise in the bottom of the riverbed with a consequent decrease in the section available for the flood flow. Besides, houses were built close to the riverbed, in a dangerous position.

d. In **Borgoratti**, there are problems of flooding of roads, with more than a meter height.Downstream of the Borgoratti bridge, the arch is partially occupied by **Via Del Borgo**, which is inundated. Also in this area, there is on the right side a discontinuous embankment, and on the left side, the riverbed is bordered by a road whose retaining wall is not sufficient for the outflow of the flood.

e. From downstream of this area until the bridge of **Corso Europa** there are no other significant flooding events; but there is still a risk near the area of the electrical installation due to the occupation by recent buildings.

Then, close to the footbridge below the bridge of Corso Europa, there is a relevant erosion on the right side and flooding events on the left one.The floods become more and more large towards the **Carabinieri Comando Legione Liguria** until to the **Roman bridge**.In this point, the floods and the interventions of great urgency have led to the demolition of some buildings in the riverbed.

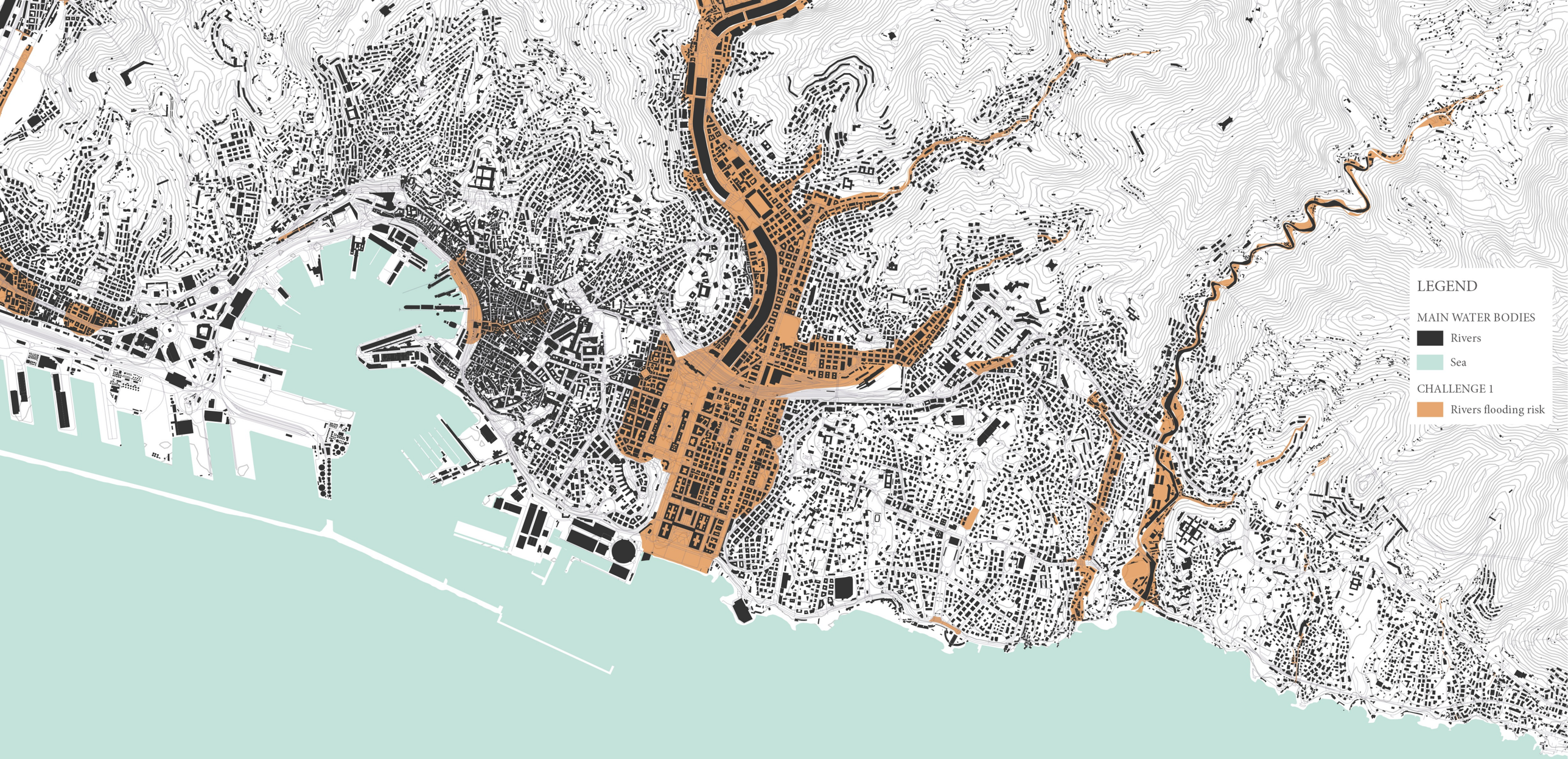
From the Roman bridge to the mouth of the river, the most significant damage were the human losses. Flood waters have spread along **Via Cembrano** and near the **railway bridge**, both right and left sides. Moreover, the space occupied by the **university building** and the sewage system have led to a significant reduction in the already insufficient hydraulic capacity of the watercourse, causing the leakage of large masses of water with disastrous consequences.

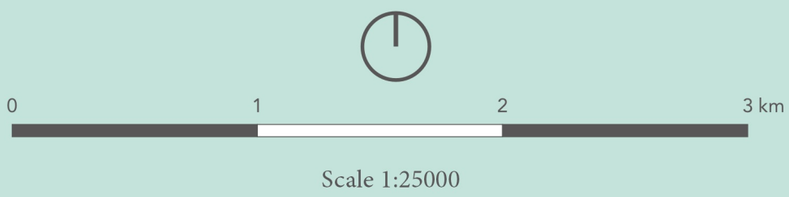
Map 3. Sea level forecasts at 1.5 Celsius degrees temperature change. Source: Own elaboration by combining information from global warming Climate Central Map and SSP scenary according to NASA approximations.

Map 4. Sea level forecasts at 2 Celsius degrees temperature change. Source: Own elaboration by combining information from global warming Climate Central Map and SSP scenary according to NASA approximations.

Map 5. Sea level forecasts at 3 Celsius degrees temperature change. Source: Own elaboration by combining information from of global warming Climate Central Map and SSP scenary according to NASA approximations.

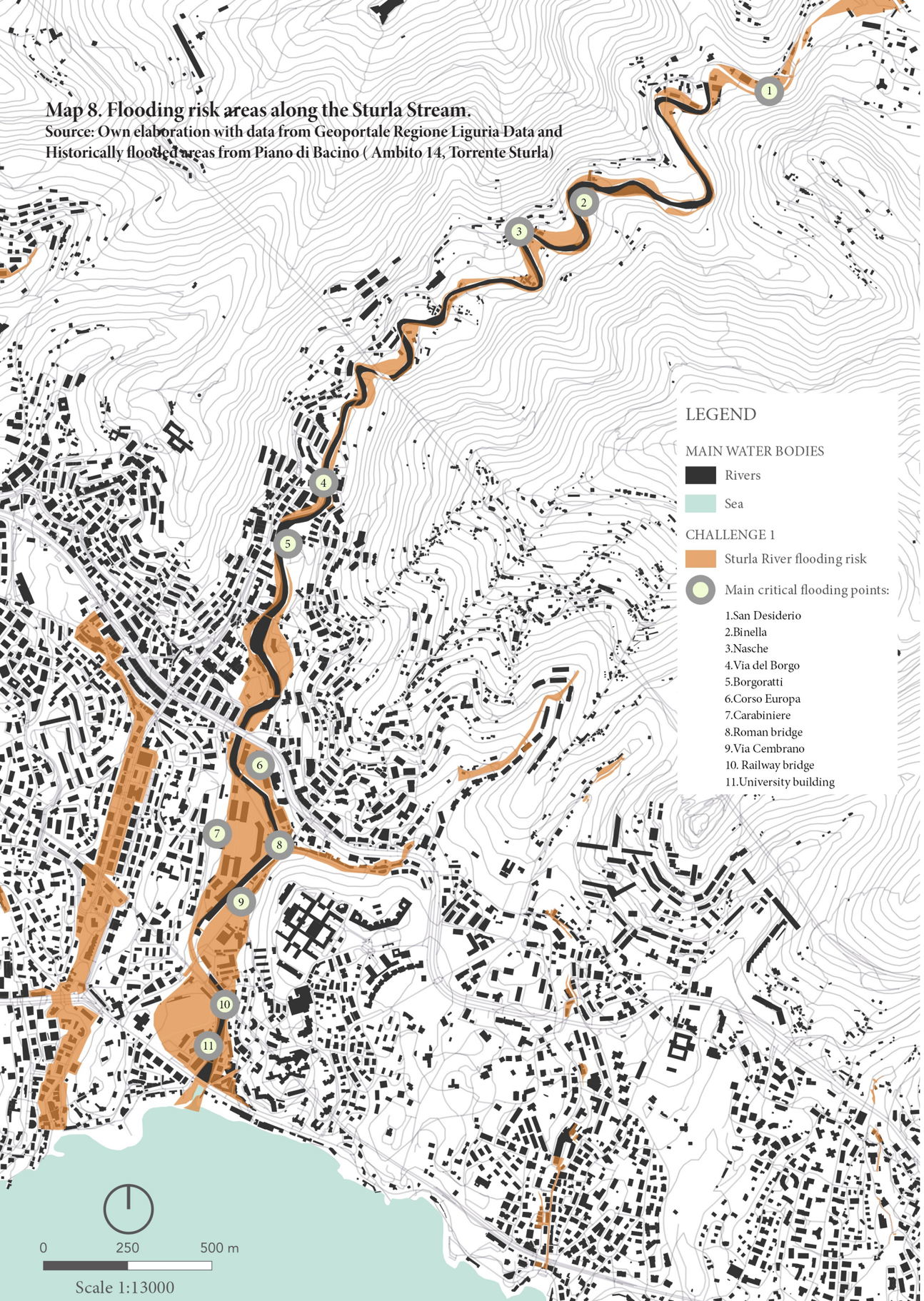
Map 6. Sea level forecasts at 4 Celsius degrees temperature change. Source: Own elaboration by combining information from global warming Climate Central Map and SSP scenary according to NASA approximations.





Scale 1:25000

Map 7. Flooding risk areas along the Sturla Stream. Source: Geoportale Regione Liguria Data



Map 8. Flooding risk areas along the Sturla Stream.
Source: Own elaboration with data from Geoportale Regione Liguria Data and Historically flooded areas from Piano di Bacino (Ambito 14, Torrente Sturla)

Challenge 2

Erosion and Sedimentation of coastline and rivers

There is a close connection between the first challenge and this second one, because the sea level rise and the flooding of rivers necessarily contribute to the phenomenons of erosion and sedimentation. Regarding this topic, it is possible to observe that:

> *One of the most certain consequences of global warming is an increase of global (eustatic) sea level. The resulting inundation from rising seas will heavily impact low-lying areas; at least 100 million persons live within one meter of mean sea level and are at increased risk in the coming decades. The very existence of some island states and deltaic coasts is threatened by sea level rise. An additional threat affecting some of the most heavily developed and economically valuable real estate will come from an exacerbation of sandy beach erosion. As the beach is lost, fixed structures nearby are increasingly exposed to the direct impact of storm waves, and will ultimately be damaged or destroyed unless expensive protective measures are taken. It has long been speculated that the underlying rate of long-term sandy beach erosion is two orders of magnitude greater than the rate of rise of sea level, so that any significant increase of sea level has dire consequences for coastal inhabitants".*
> (Zhang et al., 2004)

Moreover, according to ECO-information in European ports (1999) several water streams, often full due to rain, discharge into the sea sedimentation material and dangerous substances from chemical and manufacturing plants situated along the rivers.In addition, the problems of erosion and sedimentation reduce the efficiency of the ports.

In order to understand the erosion and sedimentation phenomenons, they are going to be described as follows:

Coastline

Regarding these two natural processes along the coastline of Genoa, it is possible to obtain information from the Geoportale Liguria, the evolution of the coast through the satellital images from Google Earth and historical maps. The available years correspond to 1850,1944, 1973, 1983,1993,2003,2013,2016 and 2021.

The analysis has considered a comparison between the years 1850, 1944 and 2021 and then a comparison between the group of years 1973 -2016 in confrontation with 2021. In the first case, the years 1850 and 1944 show a "shorter" coastline compared to 2021. By

this current year, the coast has increased its size, possibly owing to the incrementation of coastal infrastructure and some sedimentation process. Nevertheless, if we compare the situation from the 70´s until nowadays, also erosion has been evident in certain areas.(see maps 9,10,11 and 12)

According to PTC della Costa (*Difesa costiera e ripascimento delle spiagge*) the expansion of the Ligurian beaches into the shape we know today, began in the XVII century with the spread of the practices of terracing and plowing in agriculture, which progressively reduce the forest cover of hilly slopes and plains, increasing considerably the transport of solids from waterways into the sea. Moreover, the fluctuations due to climatic variations in that period favoured an abundance of precipitation.

Previously the coasts were much more jagged than today and the beaches were still very far behind the current line.Between 1600 and 1800 the gradual increase of Ligurian beaches is produced, and late 1800 it probably reaches the maximum extension of the coastline (end of the "small glacial age").In this period a condition of equilibrium prevails, in the sense that sedimentation and erosion phenomena alternate without generating any particular interest in intervening, except in some cases of defense of dwelling houses, normally located in safety distance from the sea.
The beaches and shorelines until 1800 are in fact only used for the activities of fishing, hauling and shipbuilding, and there is no need for works or interventions;except for the restorations and maintenance of the historical ports of Porto Maurizio, Savona and Genoa. Afterwards, the construction of the new coastal railway line ("of the Ligurian Riviere") between 1857 - 1880 had consecuences due to the short construction time, the technical choices and low financial means.The effect was not only the unavoidable consumption and direct reduction of the beaches surface, but also the necessity of defensive works consisting of rocks reefs on the coast. These rock reefs, due to their rigidity and extension represented the first strong element of disturbance in the meteomarine dynamics along the Ligurian coast.

It was the first phenomena of erosion movements that triggered a chain effect process of defensive works, which has reached in the last 20 years a point of exasperation.

From the beginning of 1900 until the phase of "reconstruction" after the Second World War, the coast changes were not comparable to those connected to the railway line construction. Nevertheless, the first decades of the '900 experimented an increasing of collection of aggregates materials from the riverbed and the coast for construction purposes, which were enhanced by the improvement of the means of collection and transportation. This activity led to the phenomenon of impoverishment of material along the coast, being from now on one of the main causes of the accentuated erosion of the Ligurian coasts.

In addition, the first expansions of tourist resorts along the coast, resulting in construction of roads and promenades that in some cases "eat" directly parts of the coastline and generate other defensive works, as well as the increase in extension of the commercial ports of Savona and Genoa and the starting of the railway line duplication were part of this coast reduction.

Then, during post-war reconstruction phase and the years of the tourism-building boom (1960-1990), besides the realization of great infrastructure that create new works of defense, the coastal dynamics was affected by three main processes:

1) In the immediate post-war period, the difficulties and costs of transporting materials led to a heavy removal of aggregates from the main Ligurian basins.

2) After the 60's, the development of the tourist economy caused not only the expansion of towns along the coast, but also to the construction of the first marinas.

3) Also after 60´s, the economic importance and the spread of the use of beaches for bathing induces municipalities and concessionaires to no longer be able of managing the beaches erosion phenomena with the same level of pertinence that could afford the ancient populations who used the beach only for their own fishing activities.

Nowadays, in despite of the stability conditions of the sandy coast in the stretch located at the mouth of the Sturla River between Vernazzola and Scoglio dei Mille, the erosion phenomena is present too along the coast.

Along the Sturla Stream

Regarding the tributary watercourses of the Sturla, short and little ramified, it is possible to find erosion, usually strong, with very incised riverbeds and frequent phenomena of slope base undermining and consequent landslides. (*Piano di Bacino Stralcio per la tutela dal rischio idrogeologico, Ambito 14 Torrente Sturla*)

Nevertheless, in order to understand the sedimentation and erosion processes along the Sturla River, its main course could be divided into three sections (see fig.23-24) considered homogeneous (*Piano di Bacino Stralcio per la tutela dal rischio idrogeologico, Ambito 14 Torrente Sturla*) :

Tract I: Via Apparizione - Foce
Tract II: Molino Maccagno - Via Apparizione (Borgoratti)
Tract III: San Desiderio - Molino Maccagno

The following is a description of the watercourse, according to the three sections indicated, proceeding from upstream to downstream:

Tract III: San Desiderio - Molino Maccagno

Between San Desiderio (at the confluence with the Poma tributary stream) and Molino Maccagno, there is a winding course, with the formation of several meanders. Along these meanders, main settlements (Nasche, Binella, Cascine, Molino Maccagno) are concentrated without maintaining the sufficient safety distance.

Towards Nasche the riverbed flows mainly on alluvial sediments while downstream, at the confluence with the Rio Premanico, the outcrops of rock prevail.

The main geomorphological problems identified in the interaction between hydrography and slopes are constituted by some phenomena of instability that can be attributable to the erosive action of the stream. Those landslides are the main sources of solid material that the watercourse transports during flood events.
For long stretches of the stream, there is the lack of a continuous embankment: indeed,

Map 9. Sedimentation - Land Reclamation.

Source: Own elaboration with data from Geoportale Regione Liguria,satellital images from Google Earth and historical maps from Poleggi & Cevini (1981)

LEGEND

MAIN WATER BODIES

Rivers and Sea

COASTLINE EVOLUTION

Coastlines Comparison

1850

1944

2021

0 1 2 3 km

Scale 1:25000

Map 10.Erosion.

Source: Own elaboration with data from Geoportale Regione Liguria,satellital images from Google Earth and historical maps from Poleggi & Cevini (1981)

LEGEND

MAIN WATER BODIES

Rivers and Sea

COASTLINE EVOLUTION

Coastlines Comparison

2021

1973 - 2016

Fig.23.Sturla river tracts. Piano di Bacino Stralcio per la tutela dal rischio idrogeologico,Ambito 14, Torrente Sturla.

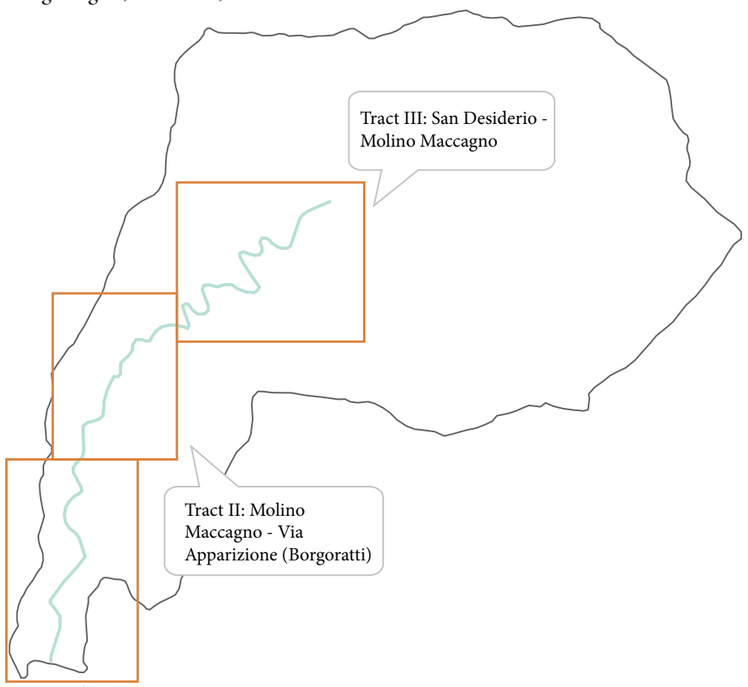


Fig.24.Sturla river and main tributary rivers. Piano di Bacino Stralcio per la tutela dal rischio idrogeologico,Ambito 14, Torrente Sturla.

there are houses along the shores, representing a considerable risk. Another important fact is the presence of sewerage crossing in Binella, which constitutes a real barrier to the watercourse. This kind of elements causes a considerable deposit events upstream, with a consequent rise in the level of the riverbed, causing the flooding of previously safe areas.

At the confluence of the Rio Premanico, the stream flows over alluvial deposits, the size of which seems to increase roughly gradually from one point of maximum curvature to the next one. Immediately upstream of the meanders, there is frequently a considerable accumulation of coarse material.

The fact that downstream of the bridles, the riverbed is mainly in rock while upstream is mainly in alluvial sediments, it is due to the interference of solid transport in the riverbed.

Tract II: Molino Maccagno - Via Apparizione (Borgoratti)

Between Molini Maccagno and Via Apparizione the meandering behaviour continues. After the Borgoratti bridge, the track is more straight.

Along the entire watercourse it is possible to observe a phenomenon: at the most curvy point of the meanders there are "natural stairs".Another peculiar situation is the more and more frequent recurrence of substrate outcrop in the riverbed, to the point of flowing into the rock (between Molino Maccagno and Cadighiara) with presence of local alluvial accumulations, especially on the inside of the meanders and mainly made of coarse materials.

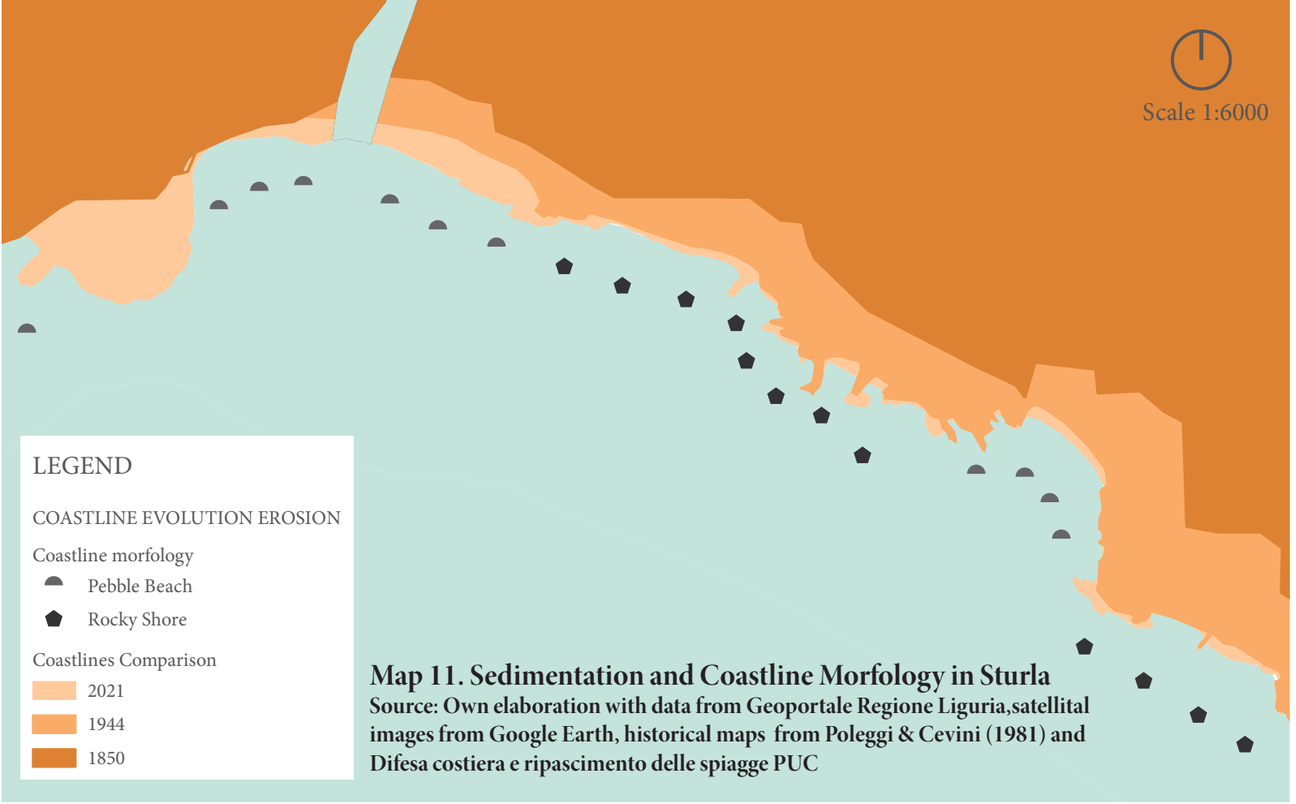
Both sides of the river are highly anthropized, especially downstream the Borgoratti bridge, where the most urbanized area start. Upstream there are groups of houses on the right shore, while on the left one, the riverbed is confined by the slope.

The main criticality of this stretch of the river consists precisely in the area downstream of the Borgoratti bridge, where in past events occurred more than a meter height floods and high sliding speeds with damages to the next bridge. Another considerable danger situation presented at this bridge is its only arch destined to the outflow of water. This one is partially blocked by Via del Borgo, which during flooding events becomes a sort of second riverbed capable of moving parked cars.

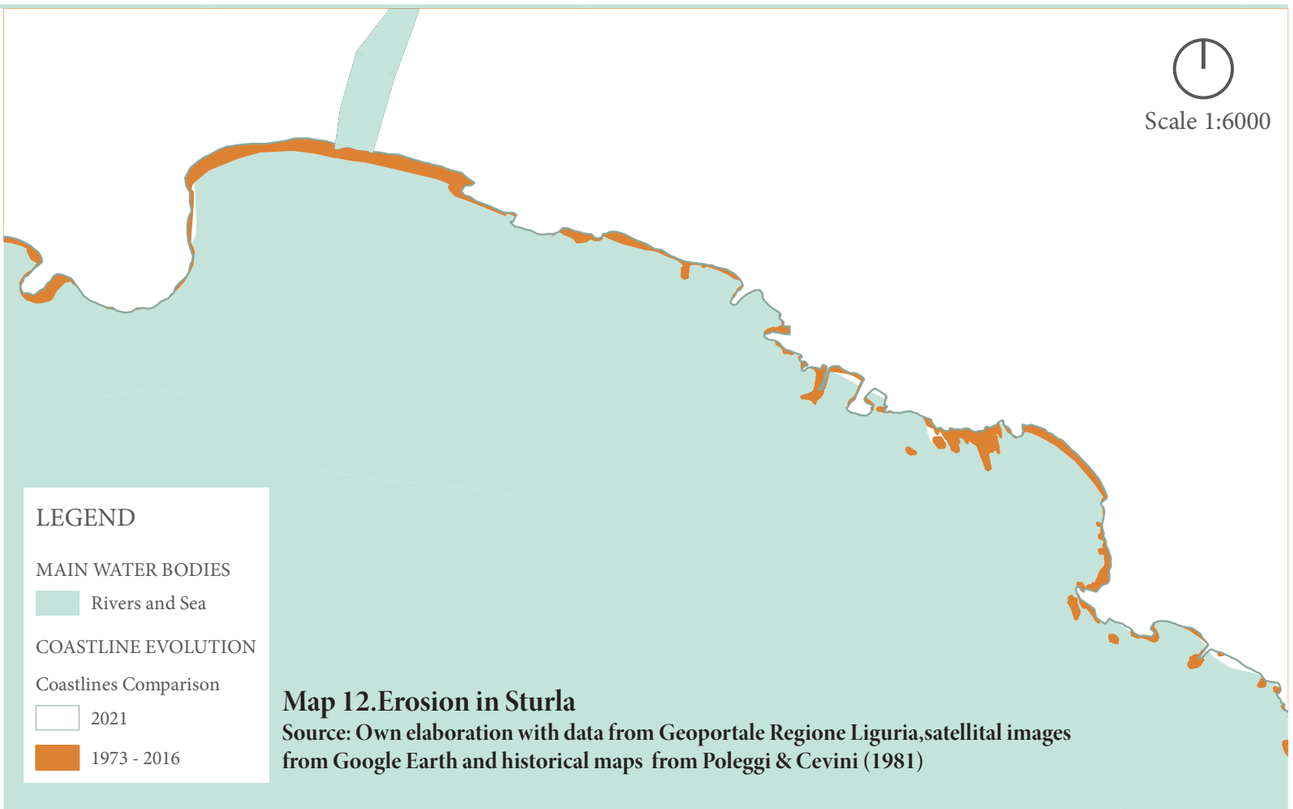
Furthermore, in this tract there are walkways that show signs of severe erosion at the bases.The embankments are discontinuous on both sides, with an alternation of slopes in a state of decay and concrete walls, not always in good condition. Also in this tract there are signs of strong solid transport, with abundant deposits.

Tract I: Via Apparizione - Foce

The final stretch of the Sturla river, between the bridge of Via Apparizione and the outlet into the sea, presents the greatest problems because the areas around the riverbed are densely anthropized.
Sometimes there are obstacles for the water outflow within the riverbed itself. The



Map 11. Sedimentation and Coastline Morfology in Sturla
Source: Own elaboration with data from Geoportale Regione Liguria,satellital images from Google Earth, historical maps from Poleggi & Cevini (1981) and Difesa costiera e ripascimento delle spiagge PUC



Map 12.Erosion in Sturla
Source: Own elaboration with data from Geoportale Regione Liguria,satellital images from Google Earth and historical maps from Poleggi & Cevini (1981)

end of the Sturla river has been affected by floodings which have caused considerable damage, both economically and in terms of human lives. The riverbed still has a tendency to be meandering, with a sharp curve at the railway bridge, downstream of which, then, has been rectified.

Sturla basin lithology and coastline morphology

It is important to take into consideration the morfology and lithology of the study site, in order to understand how the erosion and sedimentation processes are acting according to the materiality of the coastline and the basin.

Sturla basin lithology

In accordance with the Piano di Bacino Stralcio per la tutela dal rischio idrogeologico (Ambito 14, Torrente Sturla), the study basin has a reduced lithological variability due to the limited extensions of the area.

Geological formations emerging in the Sturla basin belong to the Unit of M. Antola, widespread throughout the Levante area of the Province of Genoa .The type of deposits characteristic of this unit present a rapid bacinal overflow, referred in literature as flysch. In particular, the Antola flysch, or the youngest formation belonging to the Unit is often called as Flysch at Helmintoidea labyrintica due to the presence of bioturbations traceable to Helmintoides slopes and Chondrites tunnels.

The stratigraphically underlying formation of the Flysch of M. Antola, called Argilliti di Montoggio is instead characterized by the predominance of hemipelagitic deposits (the normal sedimentation of the basin) and is considered the level of detachment of the Unit during the orogenetic process.

Furthermore, shape of the basin and the modelling of the slopes are influenced not only by tectonics, but also by the structure and lithology, in particular by the erodibility of the different lithotypes (emipelagiti, calcilutiti, marnosiltiti, marne calcaree, calcareniti). The slopes are high in the outcrop areas of the Calcari dell'Antola while, where the Argilliti of Montoggio emerges, the acclivity is much lower.

Coastline morfology

Morfology is constituted basically by sandy-pebble beach and rocky shoreline.
This pebble beach was famous especially in the last century, and Genoese families used to choose it for the holiday. (PUC, *Difesa costiera e ripascimento delle spiagge*)

In the map 11 we can observe the location of these different coastline compositions.

Challenge 3

Urbanization and Water Pollution

Industrial, urban and commercial activities representing the major polluting sources.

Most of the port activities are potential sources of water pollution. According to ECO-information in European ports (1999), ships repairing, steel production and electricity production from coal power stations are examples of those activities. Furthermore, commercial, military and touristic activities contribute to the pollution of the marine system.

In accordance with the Piano Urbanistico Comunale di Genova (PUC) large commercial ports represent activities with a significant environmental impact: a primary cause of degradation is represented by the distortion and occupation of the coast and the seabed by infrastructure and defence works; they delimit bodies of water of limited extension and the little water exchange makes pollution phenomena more evident, especially of chemical nature: it is due to various kinds of toxic substances (hydrocarbons, heavy metals, chlorinated substances) linked to merchant traffic, wear and tear of metals and paints, chronic or accidental spillage during the loading and unloading phases. Another highly polluted practice is the periodic dredging operations necessary to maintain the practicability of the ports, however contaminating sediments tend to degrade the seabed, altering its chemical and particle size characteristics.

The tourist port reproduces, fortunately on a smaller scale, the potential impacts of the commercial one: the bilge water and small fuel spills, the use of paints and other substances used in treatment of hulls, cloacal slurry, etc, causes chemical and physical - bacteriological pollution that insist on water mirrors with little water exchange and seabed subject to periodic dredging, as it was mentioned before.

Therefore, the ports of Genoa are sites where environmental degradation is most severe; both water and sediment from the seabed are contaminated with hydrocarbons and other harmful substances.

It is important to mention that also high urbanization and the particular configuration of the area (a narrow strip of land between the mountains and the sea) which increases the density of this urbanization, are part of the degradation of the quality of Genoa waters.

There are urban waste water depuration plants, but some of them operate in overloading conditions. Moreover, heavy rains, maintenance problems and overfeeding of industrial waste waters, still contribute to compromise the good operating conditions of depuration plants.The morphologic characteristics combined with the discharge of urban waste waters represent a high environmental impact, because reduces the exchange of oxygen.(ECO-information in European ports,1999).

Regarding the WP9-Relation Port Authorities and Cities / Industry Case studies of Genoa and Marseille ports (1999), it is possible to conclude that environmental problems of Genoa port waters are mainly due to the presence of several discharges of untreated urban-domestic waste water (often discharged into the sea by rivers), industrial waste water only partially purified, first rains, maritime traffic (civil and commercial), loading and unloading of goods.

According to the Piano Urbanistico Comunale di Genova (PUC), domestic discharges produce only secondary chemical pollution (hydrocarbons, surfactants,phenols); the main alterations concern mainly the intake of organic matter, which manifests itself with bacterial contamination, increased nutrients and turbidity of water.

The situation along the Ligurian arc seems to be improved significantly compared to the 70's - 90's decades, thanks to the recovery water programme, it has been possible the adaptation of a system of collection and purification of urban waste water, before it is getting into the sea. This water treatment has had a general reduction of bacterial contamination and nutrients.However, it is still necessary to complete the water rehabilitation plan of the Genoese coastal strip where signs of degradation remain, in particular a constant microbiological pollution.

These problems arise from two distinct situations:

1- Adaptation of sewerage, purification and sea discharge systems must be completed, and therefore it is found the residual presence of untreated or partially treated wastewater that deliver to the sea, especially carried by waterways (rivers).

2-Wastewater treatment system and its disposal arrangements require changes improving purification and identifying optimum entry points (depth, distance from the coast and appropriate current conditions). The purification, the point and the depth of the input ensures the appropriate abatement of bacterial presence on coastal waters.

Signs of this need for adjustment are the episodic cases of high bacteriology or surfactant values (present in detergents) and the high frequency of these cases in the band (stations 500 meters from the coast) affected by the discharge of pipelines.

Sturla situation

As regards the sewerage system and sewage treatment plants, the Sturla valley (*Piano di Bacino Stralcio per la tutela dal rischio idrogeologico, Ambito 14 Torrente Sturla*)is served by a sewage treatment plant located near the mouth of the creek and which discharges into the sea by underwater pipelines. This plant serves approximately 58.000 inhabitants, practically only civilians, with great problems of maintenance and precarious depurative yield.

At the level of biological communities the impact of domestic discharges is evident along the points of entry of conducts and mouth of streams, where changes in

biocenosis have been documented, for instance interruption or signs of distress in the Posidonia oceanica prairies. Another pollutant contribution to be considered in some specific times and areas is the organic type pollution by recreational boating. (PUC)
It is important to add the presence of floating waste (plastic bottles, bags, etc.) that represents a visual impact and a public opinion concern. The origins of this waste are several but it seems to be partly separated from the water disposal system (sewage, sewage treatment plants, pipelines); in particular, the most significant sources have often been found in the riverbeds of rivers and streams.

There is a bathing water monitoring (PUC- *Ambiente ed Energia*) that includes at least two checks per month during the period April-September in the approximately 400 survey sections into which the Ligurian coast is subdivided. It is important to mention that monitoring of coastal waters and marine ecosystems is carrying on by traditional studies based on the use of sentinel organisms, the so-called bioindicators.

The bacteriological quality index takes into account 2 parameters controlled by law: faecal coliform and faecal streptococci, which are considered to be the most reliable indicators of sewer contamination.The pollution classification is: strongly contaminated (class 5), contaminated (class 4), mediocre contaminated (class 3), sufficiently contaminated (class 2) and uncontaminated(class 1). According to this, Sturla Ovest is strongly contaminated (class 5) and Sturla East is contaminated (class 4).

It means that the study area presents a real water pollution problem. In the Map N°13, it is possible to observe the main sources of pollution, discharges and treatment centers. Among the main chemicals affecting the sea are: tributilstagno, IPA and mercurio. Those chemicals can be really dangerous for living organisms, including human beings.

Nevertheless this critical situation, many people carry out water sport activities in the sea for recreational or sportive reasons. As we can see in the map N°14, there is an invible network of water sport activity monitored by the Strava heatmap application.

Sea activities

LEGEND

MAIN WATER BODIES

- Rivers
- Sea

CHALLENGE 3

- Centri_di_trattamento copia copia
- Waste water pipes
- Waste water discharges
- Ships and boats routes

TYPE OF POLLUTANTS IN THE SEA

- Mercurio
- IPA
- Tributilstagno

0 1 2 3 km

Scale 1:25000

Map 13.Urbanization and Water Pollution
Source: Data from Geoportale Regione Liguria

LEGEND

HEATMAP

Water Sport activities

Ships and boats routes

0 1 2 3 km

Scale 1:25000

Map 14.Water Sport Activities

Source: Own elaboration with data from Strava Heatmap, https://www.strava.com/heatmap#11.92/9.21639/45.45356/hot/all

Challenge 4

Fires nearby water bodies

According to the Comune di Genova (*Cosa fare in caso di incendi boschivi, 2021*), it is common for the Ligurian Region the emission of the State of Danger for forests fires during the summer season due to the climatic conditions (as for example reduction of precipitations) and the dryness of the land.

The conformation of the territory of Genoa, delimited by green areas, is prone to the "interface fires", it means fires that occur in forested areas close to the urban fabric, being a high risk for people, housing and infrastructure.

In this proposal, the focus will be on the fires nearby aquatic ecosystems, in this case the rivers, because they have a direct impact on the changes in the sea and what is happening to Posidonea oceanica too.

There is an important influence on riparian and wetland vegetation when they are consumed by fire, because nutrients are mobilized, runoff and erosion increases and soils may be altered. Besides habitat changes occur and some species could be benefitted from it and others may be impeded.(R. J. Bixby et al, 2015)

Therefore, the critical points to be intervened regarding forest fires, will be those areas close to the Sturla stream.(see Map15)

Temperature and Wind conditions

From the thermal point of view, the city is perfectly within the values of the Mediterranean climate. The coldest month is January, which averages temperatures of at least 6,4 ° C and at most 11,5 ° C, with an average of 8,8 ° C. The hottest month is August respectively with a minimum temperature of 21.4 C, a maximum of 27.2 C and average of 24.3 C.
Favorable characteristic of the Genoese climate is the low temperature range, both diurnal and annual.The lowest temperature that can be
averagely recorded at least once a year is equal to -2 C. The highest temperature can be recorded on average at least once a year is instead equal to 32 C. With regard to heat peaks, the absolute maximum is 37,0 C recorded on July 4, 1952. (PUC, *Clima e Microclima)*

Nevertheless, these stable general weather conditions can present alterations due to climate change. As explained by World Meteorological Organization (WMO),

there has been a warmest five-year period on record: *"the average global temperature for 2015–2019 is on track to be the warmest of any equivalent period on record. It is currently estimated to be 1.1°Celsius (± 0.1°C) above pre-industrial (1850–1900) times. Widespread and long-lasting heatwaves, record-breaking fires and other devastating events such as tropical cyclones, floods and drought have had major impacts on socio-economic development and the environment".* (Landmark United in Science report informs Climate Action Summit, 2019)

Long-lasting heatwaves and record- breaking fires will tend to happen during the warmest months, representing a major vulnerability that can be even favored by wind conditions.

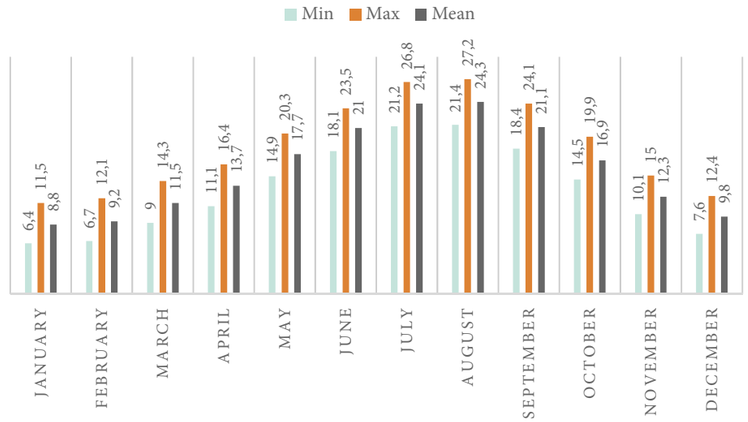


Fig.25.Temperature in Genoa, amount of Celsius degrees per month. Piano Urbanistico Comunale di Genova (PUC)Clima e Microclima.

Again, according to PUC (*Clima e Microclima*) Genoa can be defined as a quite airy city (see fig.26). Its 2.5 m/s of average annual wind speed, results beneficial on air pollution. During the winter months (the most ventilated, with averages of 2.7 m/s) the winds are associated to the passage of perturbations and atmospheric depressions (in Genoa it often rains "in diagonal").

However, during, the summer the breezes keep the atmosphere in motion. For these reasons, the prevailing currents in the winter semester are those from the northeast and from the north (winds associated with cyclones of the Gulf of Genoa) while in summer the main directions of origin are from the southwest and northeast (sea breezes and earth).

Also from the analysis of windy days (defined as those with average wind speed above 3,3 m/s), the results do not change substantially, with

maximum occurrence in January and December (5 windy days, against an average of 2 days). As far as the absolute maxima is concerned, there are no statistically significant observations available, it is possible only to affirm that wind in the city can reach speeds exceeding 25 m/s, with gusts of limited duration although, on average once a year.

In the fig.27 is represented the direction of winds along the year and warmest months that can be affected by winds, increasing the fire risk.In conclusion, during the warmest months, those prone to increase the risk of fires, are the most windy months too. It means a doble hazard due to temperature and winds direction.

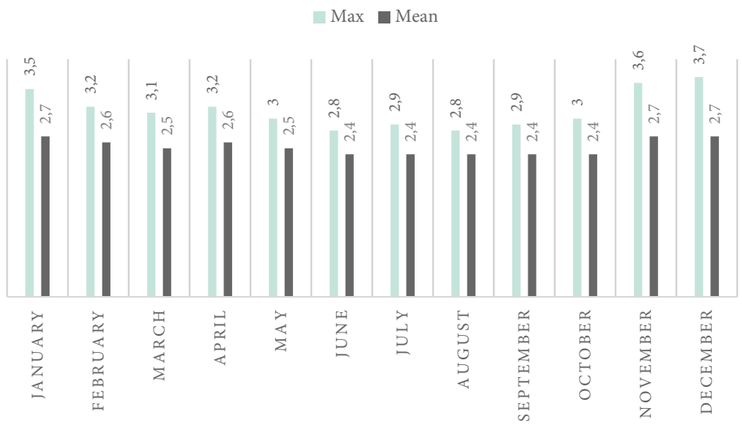


Fig.26.Wind speed in Genoa, amount of m/s per month. Piano Urbanistico Comunale di Genova (PUC) Clima e Microclima.

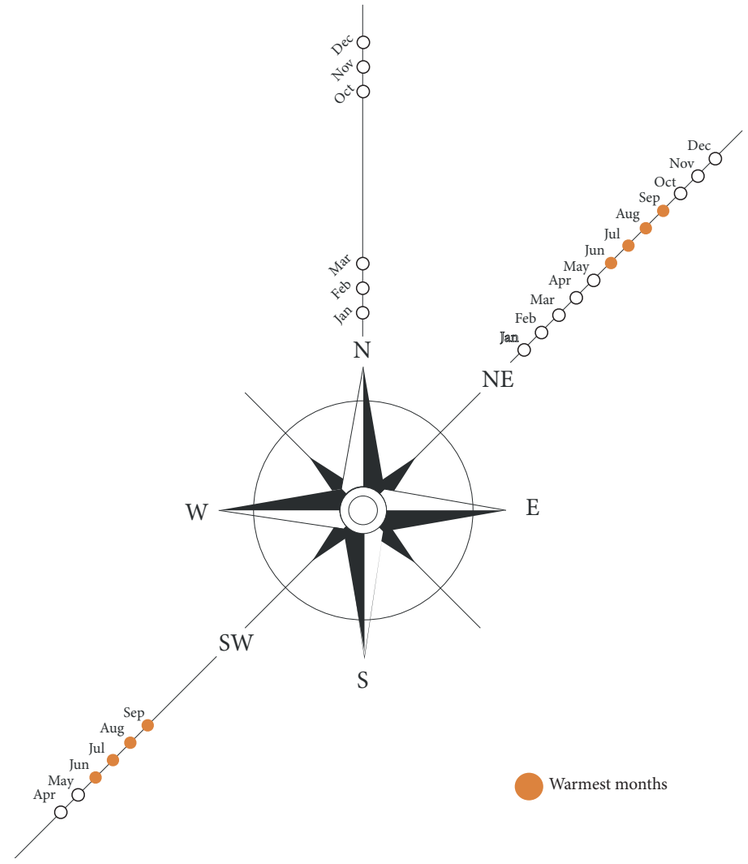


Fig.27. Compass rose, showing the direction of winds along the year and warmest months that can be affected by winds, increasing the fire risk .Own elaboration with data from Piano Urbanistico Comunale di Genova (PUC) Clima e Microclima.

LEGEND

MAIN WATER BODIES

Sea

Rivers

CHALLENGE 4

Fires

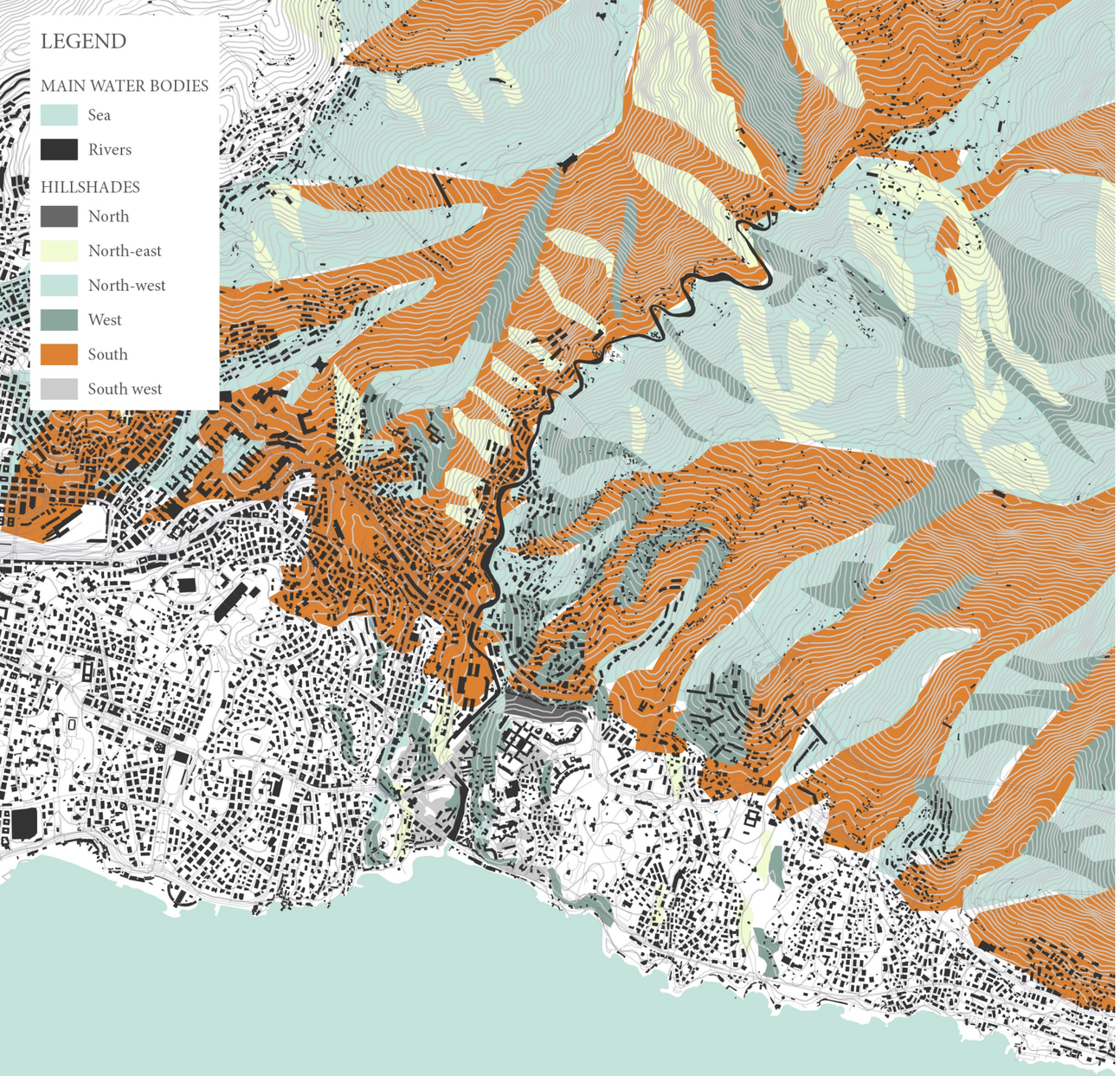
Fires nearby Sturla Stream

0 1 2 3 km

Scale 1:25000

Map 15.Fires

Source: Data from Geoportale Regione Liguria



Map 16.Hillshades in relation to wind direction and fire danger areas
Source: Data from Geoportale Regione Liguria

How do wildfires affect water bodies?

Wildfires can have immediate and long term effects on rivers, lakes, and streams. After burning vegetation, the ground's soil becomes hydrophobic and is unable to absorb any water. This creates what is known as stormwater runoff, according to the Center of Watershed Protection.

Stormwater runoff is rainflow that travels over the surface of the ground. Typically, stormwater runoff is created when rain falls on roads, parking lots, or other paved surfaces that do not allow the absorption of water. This water allows the transportation of harmful chemicals, various pollutants, and other damaging materials into streams, rivers, and large bodies of water. Homes destroyed in a fire risk the possibility of exposing dangerous materials like asbestos, and lead paint. Ultimately, these materials can be detrimental to our health and environment. They have the potential to upset the balance of water ecosystems, containment drinking water, and pollute essential nutrients and healthy resources.

After the destruction of vegetation, post-fire flash floods become a threat. These floods introduce heavy metals from ash and soil into waterways. They destroy underwater vegetation and force marine life to relocate.

Without trees, vegetation, and a stable soil structure; watersheds that supply drinking water become contaminated by ash, debris, and heavy metals. Resources for drinking water take a long time to purify and can be costly for surrounding communities.

Slope influence

Genoese climate is strongly influenced by the shape of the city: the Apennine hills develop parallel to the coast line and are crossed by numerous valleys that extent inland. The altitude of the Comune varies in a wide range, between the sea level and 1183 m (Mount Reixa). Moreover, orography dictates the greater or lesser exposure to the winds of the different areas of the city. Morphology of the city's territory as described above generates significantly different meteorological conditions between the coastal belt, including the central amphitheatre of the city, the inner zones and the reliefs. (PUC,*Clima e Microclima*)

There are 6 main hillshades directions in the study area: north, north-east, north-west, west, south, south-west. On the other hand, the area affected by fires has 4 main hillshades directions: south (the biggest in size), north-east (second in presence), north-west and west.

If we compare the study area hillshade directions, especially the south and north-east ones and the wind directions, it is possible to conclude that fires can be feed by the winds coming from the south-west and north-east, which are basically in the same direction as the slopes, so it means a direct impact against the relief.

Those are the main directions during the summer months, meanwhile the winds from the north seem do not affect in terms of fires, because they are present during the winter period.

Challenge 5

Loss of Biodiversity

In research from Bianchi et al. (2019), since 1980-90s a rapid temperature increase has occurred and it has been accompanied by a dramatic and unprecedented changes in the biota and communities of the Ligurian Sea.

Some of those changes have been for example the presence of warm-water species due to the warmer winters; some of them invasive alien species, that are concerning because of their competition against autochthonous species. Moreover, the summer heatwaves cause mortality in marine organisms and new marine diseases appear.

Both human pressure and climate change cause variations in species composition and community structure in different habitats. This implies biotic homogenization, reduction of diversity, invasive aliens dominance and also a reduction of the resilience of Ligurian Sea ecosystems. In 2010 another phase of rapid warming has apparently started and again there are certain clues that suggest further biological changes. (Bianchi et al.,2019)

In accordance with the Piano Urbanistico Comunale (PUC -*Ambiente ed Energia*) the prairie of Posidonia is completely disappeared in the harbour areas of Genoa and no more exists any type of vegetation. Indeed, dead matte clods are buried under the mud that currently covers the bottom and become sometimes extracted during dredging. On the other hand, it is still possible to find this aquatic plant in the study area, along the coast where the Sturla River flows into.(see map 18, in color orange)

The dredgings carried out in the commercial and tourist ports, even when they are not contaminated by toxic substances, alter the particle size of the seabed or they bury the communities. There is a generalized impoverishment of the biocenosis that manifests itself with the disappearance of the prairie of Posidonia,sometimes replaced by Cymodocea.When these prairies are buried, the increase of turbidity then determines the rise of the lower limit of survival while texture is alterated, from sandy to silt - clay and this alteration is also in favor of the Cymodocea settlement.

Furthermore, similar effect has been caused by the landfills of aggregates produced by the great infrastructures of the last decades that have been poured directly into the sea or have been used for the construction of embankments on the coast.Further sources of degradation have been the quick practices of repairing the beach through poor quality and inert materials.

If we observe the Fig.28, the distribution of the marine angiosperm Posidonia oceanica in the Mediterranean has been reduced by a considerable amount. Areas such as Toulon and Gabes have lost Posidonia oceanica completely, and others such

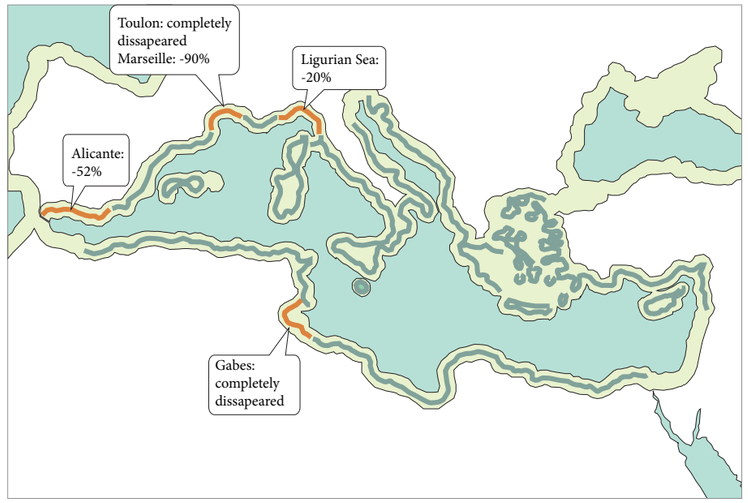


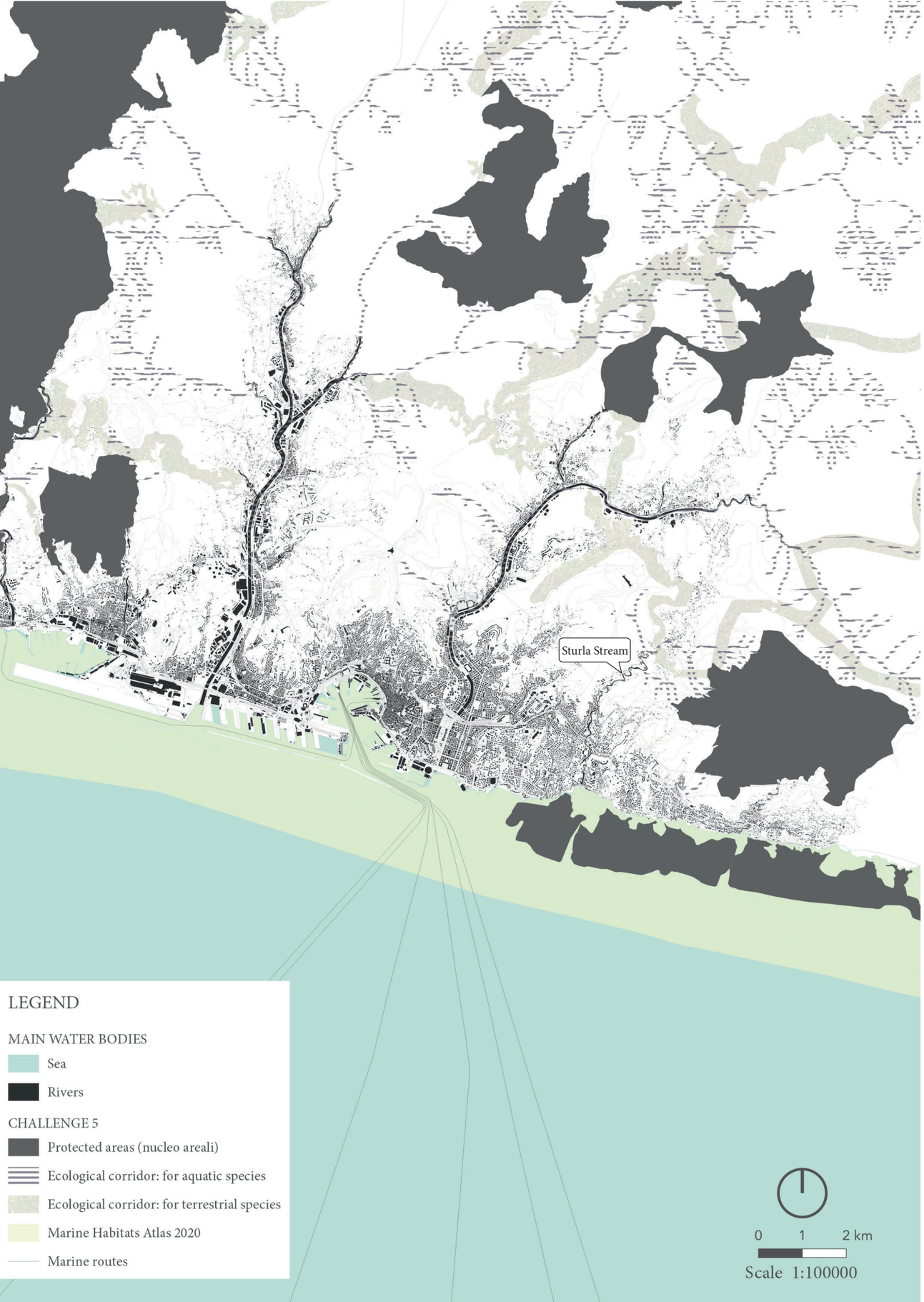
Fig.28.Distribution of the marine angiosperm Posidonia oceanica in the Mediterranean.Source: RAC/SPA - UNEP/MAP, 2014. Monitoring protocol for Posidonia oceanica beds. RAC/SPA - MedMPAnet Project.

as Marseille (-90%), Alicante (-52%) and the Ligurian Sea (-20%) have reduced its amount.

According to the Piano Urbanistico Comunale (*Ambiente ed Energia*) there are national and regional regulations that deal with the protection of the marine environment. One of these is L 979/82 *"Disposizioni per la difesa del mare"* ("Provisions for the defence of the sea") that establishes rules regarding to marine monitoring. The legislation provides the establishment of a network in order to observe the quality of the marine environment and an appropriate surveillance system on activities taking place along the coast.The activities correspond to periodic inspections of the marine environment with the collection of oceanographic, chemical, biological, microbiological and product data as well as the fight against all kinds of pollution and the management of coastal zones. Moreover, the protection of marine resources, from the ecological point of view.

In 1995 it was carried out by the Region Liguria a monitoring of coastal waters in order to know the state of marine ecosystems. This is currently one of the main knowledge tools in order to know the status of the waters of the ligurian coast belt. In the map 18 we can observe the monitoring stations for Posidonia oceanica and the marine ecosystems monitoring stations.

On the other hand, the Regional Law on the protection and enhancement of biodiversity (lr 28/2009) has established the Regional Ecological Network, consisting of all Natura 2000 sites, protected areas and functional ecological connecting areas that hold a particular importance for conservation, migration,geographical distribution and genetic exchange of wild species.The following elements and types of connection have been identified for the construction of the regional ecological network:



- Core areal sites: correspond to Natura 2000 sites and protected areas and represent the areas that need to be connected with the network.

- Punctual core sites: correspond to critical areas, of safe ecological value for functionality of the network, small or even point-like, for which, however, connections to the network are not possible. In this typology is sometimes found, for particular situations of isolation, some ecotonal zones, caves, cliffs, pools, wetlands and some minor wildlife areas.

-Ecological corridors: they are a connection of great importance for all ecological groups, but are particularly suitable for species related to watercourses, forest and grassy-shrubby environment.

As a confirmation of the environmental value of this study area, there is the existence of the Marine Site of Community Interest *"Fondali da Boccadasse a Nervi"*, where the interest of the site is due to the presence of Posidonia prairies located partly on rock partly on "matte", interspersed with Coralligenous populations.(PUC, *Sistema portuale e litorale*)

All these elements can be identified in the map 17,displaying a general view of Genoa.The main core areal sites and ecological corridors (aquatic and terrestrial) are highlighted. Moreover it is possible to observe the disconnection or connection between them. Summarizing, there are certain areas that do not have a continuity and it means an obstacle for species migration and genetic exchange.

In the specific site (see map 18), it means the Sturla Stream and the surrounding Ligurian Sea area, there are two main corridors: aquatic and terrestrial corridors that transversally cross the Sturla and one main core areal site in the sea (Posidonea prairies). Nevertheless, those important poles of biodiversity could be better connected along the stream, situation is not so clear now.

Thestream itself is a small corridor if we compare it to the biggest ecological corridors in Genoa, but it still represents a significant potential in terms of environmental impact.In the upstream areas there is a big variety of fauna and a still naturalness, offering refuge and the opportunity to feed and reproduce for many species of birds.

LEGEND

MAIN WATER BODIES

- Sea
- Rivers

CHALLENGE 5

- Ecological corridor: for aquatic species
- Ecological corridor: for terrestrial species
- Strongest Posidonia habitat
- Marine Habitats Atlas 2020
- Monitoring station Posidonia oceanica
- Marine ecosystems monitoring station
- Marine routes

Sturla Stream

0 1 2 3 km

Scale 1:25000

Map 18.Biodiversity Specific Site
Source: Data from Geoportale Regione Liguria

Design Proposal

from Sturla Stream to the Ligurian Sea

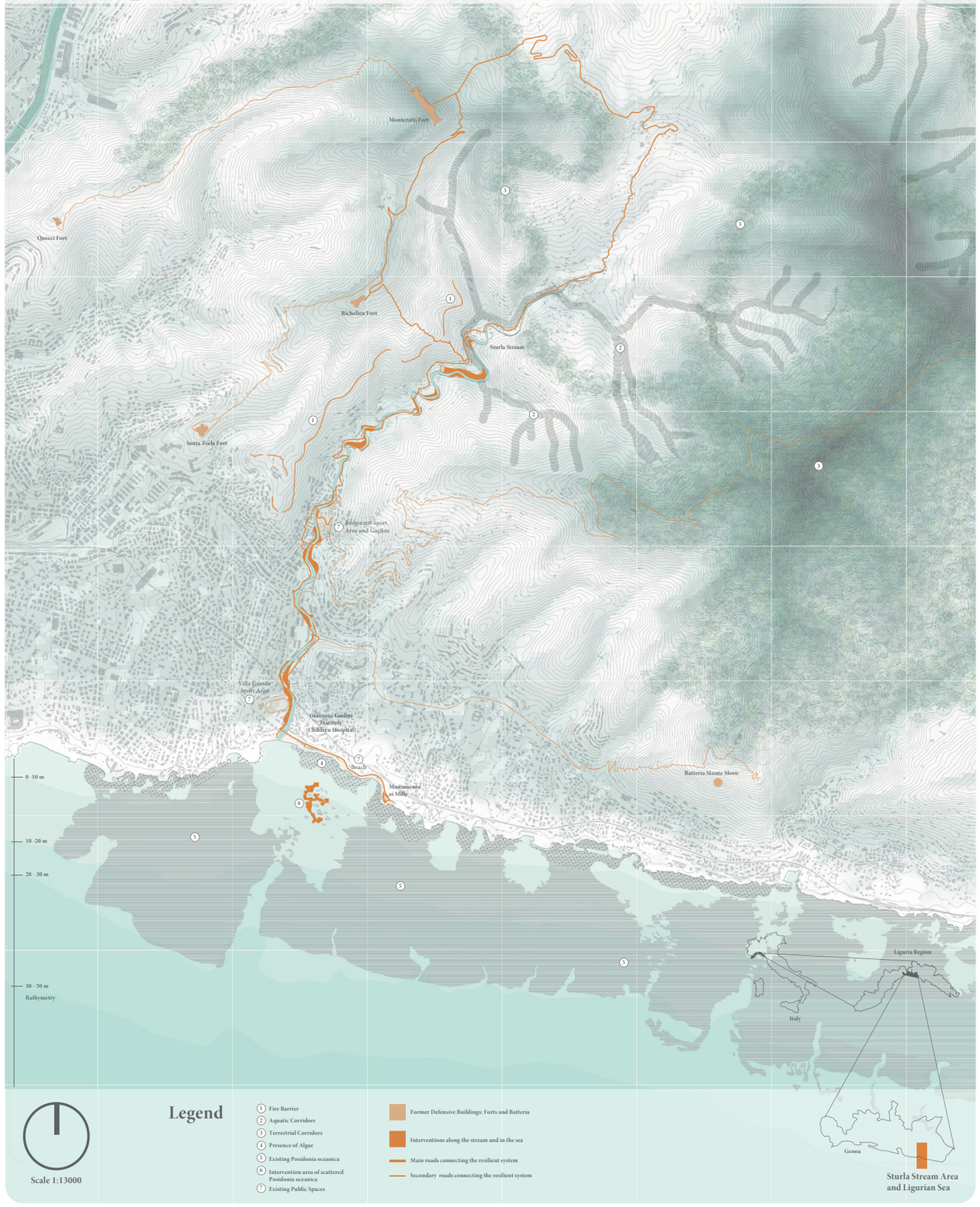
"When we try to pick out anything by itself, we find it hitched to everything else in the Universe."

John Muir

Resilient Waterscapes in Genoa:

From the Sturla Stream to the Ligurian Sea

Masterplan



Politecnico di Milano_ MSc Landscape Architecture. Land Landscape Heritage_
*Thesis Project_Resilient Waterscapes in Genoa: From the Sturla Stream to the Ligurian Sea_Advisor:*Chiara Gerelli_**Student:** *Paula Alejandra Aguilar Sanchez_940502*

Resilient Waterscapes in Genoa; From the Sturla Stream to the Ligurian Sea is a specific waterscape proposal but part of a big system. In this system the interventions along the Sturla Stream and the sea are interconnected through a main and secondary possible routes that invite to the landscape.

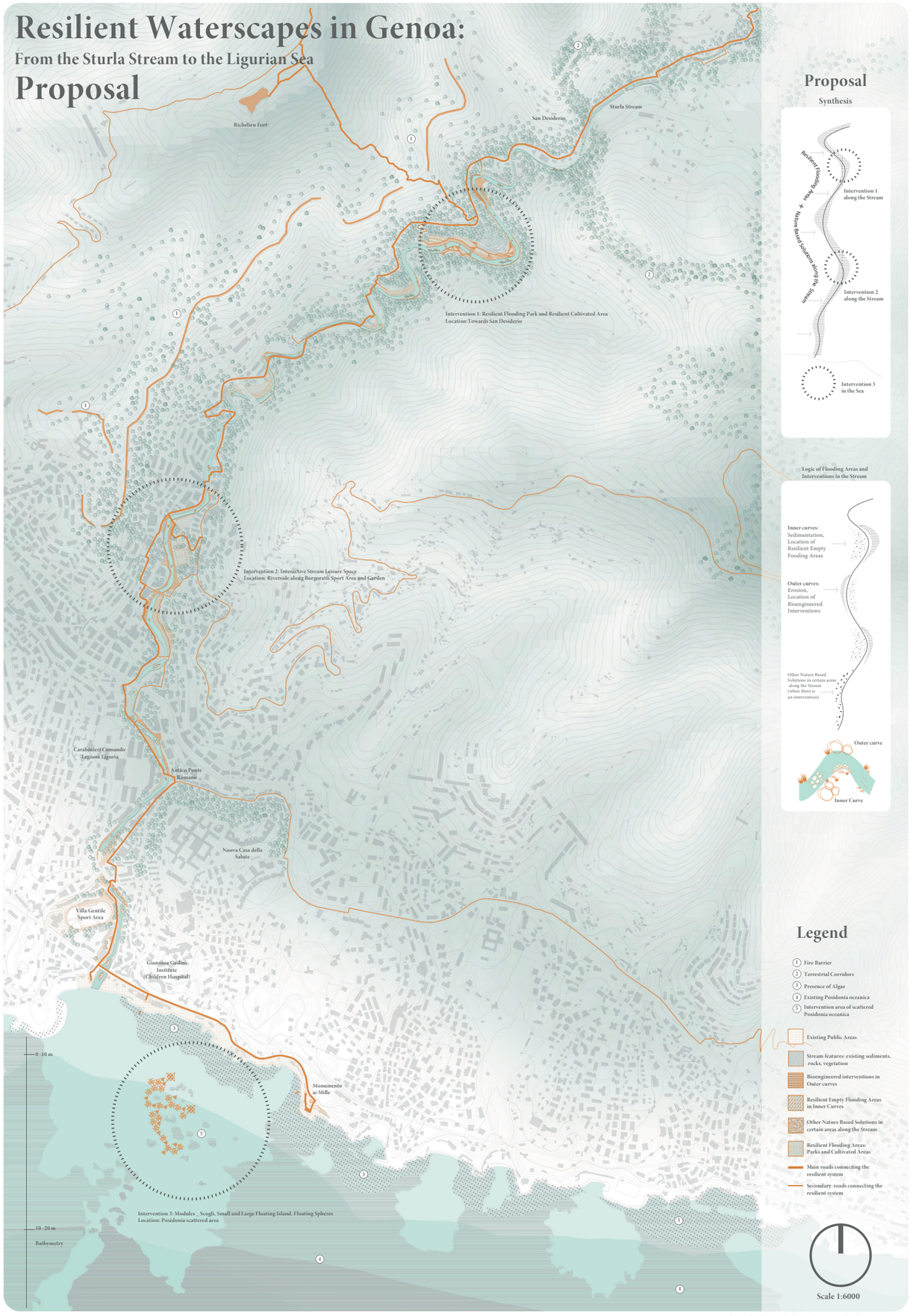
Former defensive buildings such as forts and batteria are part of the itinerary.As we can observe in the masterplan, there is a linear intervention along the stream but also certain areas increasing and decreasing in size according to the features of the context.

When the stream meets the sea, the scattered area of Posidonia represents a big opportunity of intervention, because raises the possibility of repopulation of this aquatic plant.

Resilient Waterscapes in Genoa:

From the Sturla Stream to the Ligurian Sea

Proposal



Along the Sturla Stream there are going to be present resilient flooding areas in order to reduce the stream energy during flooding events, as well as a series of nature based solutions within the stream and its banks.

Moreover, 3 specific points of intervention are going to be introduced:

- Intervention 1: Resilient Flooding Park and Resilient Cultivated Area (towards San Desiderio)

- Intervention 2: Interactive Stream Leisure Space (Riverside along Borgoratti Sport Area and Garden)

- Intervention 3: Modules _ Scogli, Small and Large Floating Island, Floating Spheres (in the Posidonia scattered area)

As important as those interventions, it is the fire barrier located in the upper part of the mountain, which defends from the fires but also agaisnt the possible soil and consequently water pollution through the chemicals released after a fire event.

Politecnico di Milano_ MSc Landscape Architecture. Land Landscape Heritage_
*Thesis Project*_*Resilient Waterscapes in Genoa: From the Sturla Stream to the Ligurian Sea*_**Advisor:**Chiara Geroldi_**Student:** Paola Alejandra Aguilar Sánchez_ 940502

Challenges and Possible Solutions

General Genoa Challenges

1- Sea level rise and flooding river risk
2- Erosion and Sedimentation of rivers and coastline
3- Urbanization and Water Pollution
4- Fires nearby water bodies
5- Loss of Biodiversity

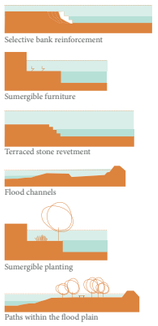
Specific Sturla Challenges

Stream

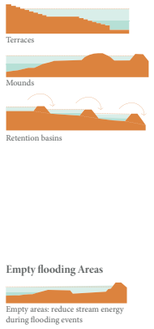
1-Flooding risk and 2- Erosion and Sedimentation

Resilient Flooding Areas

Resilient Flooding Park

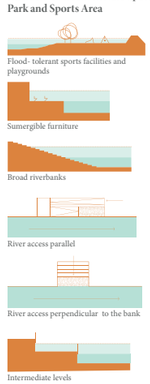


Resilient Flooding Cultivated Area



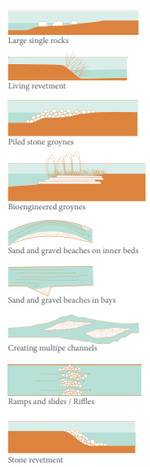
Existing Public Areas

Interactive Stream Leisure Spaces: Park and Sports Area

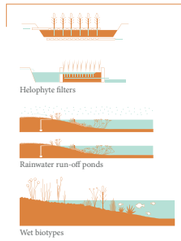


The Stream itself

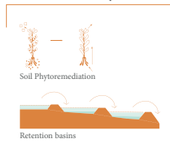
Within the Sturla Stream



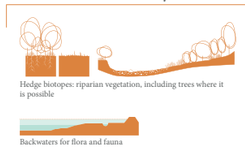
3- Urbanization and Water Pollution

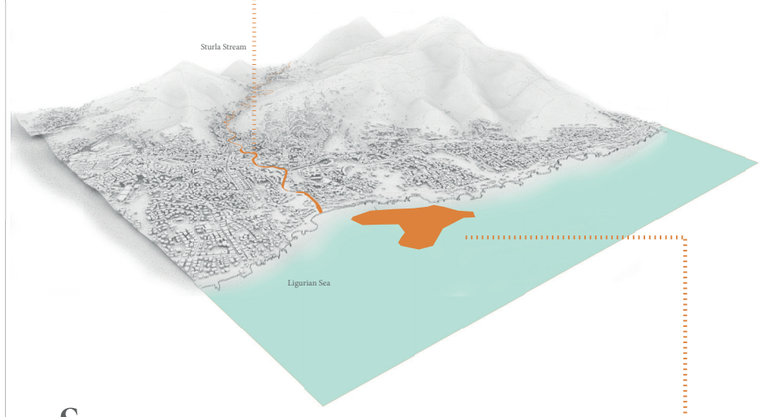


4- Fires nearby water bodies



5- Loss of Biodiversity





Sea

1- Sea level rise and flooding risk along the coast
2- Erosion and Sedimentation of coastline
5- Loss of Biodiversity

Posidonia oceanica repopulation

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Thesis Project_*Resilient Waterscapes in Genoa: From the Sturla Stream to the Ligurian Sea*_**Advisor:***Chiara Geroldi*_**Student:** *Paola Alejandra Aguilar Sánchez*_ *9405502*

The 5 challenges present in Genoa are the same challenges in the Sturla area, for this reason they have been analized and classified according to their presence in the stream or in the sea.

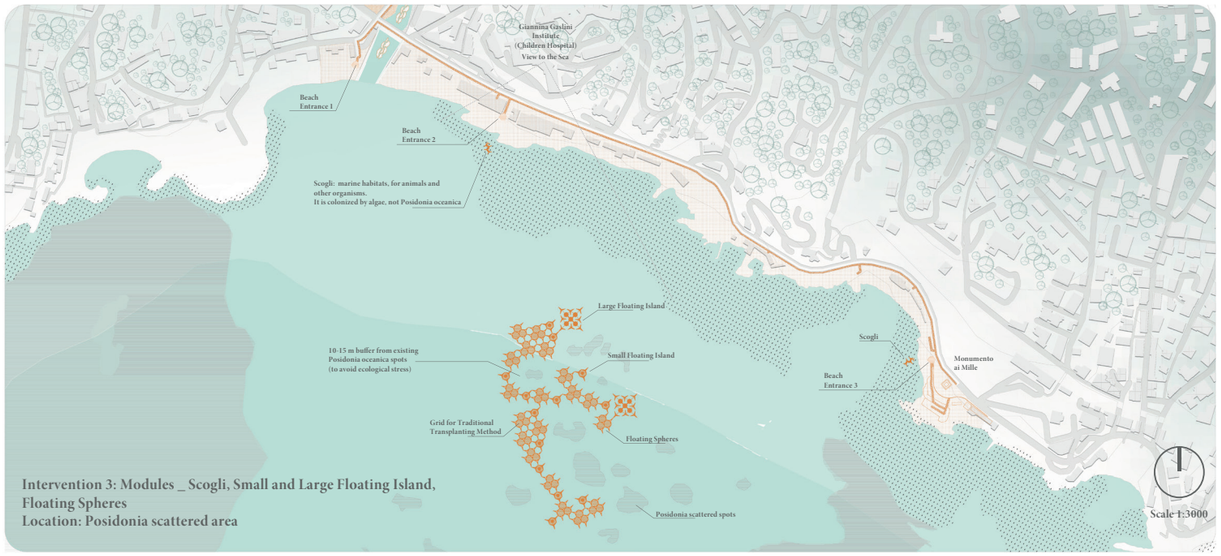
Therefore, regarding the stream we can observe different nature based solutions oriented to counteract the flooding risk and sedimentation, water pollution resulted of urbanization process, fire nearby water bodies and loss of biodiversity. All these techniques can be applied in the 3 main proposed areas:

- Resilent flooding areas : resilient flooding park, resilient flooding cultivated areas and empty flooding areas.
- Existing Public Areas: Interactive Stream Leisure Space.
- The Stream itself: within this watercourse there are things happening.

On the other hand, the main intervention to address challenges in the sea is the Posidonia oceanica. Through the Posidonia repopulation, problems such as sea level rise and flooding coastal risk, erosion and sedimentation and loss of biodiversity can be diminished just if we can increase the amount of this aquatic plant in the sea.

Posidonia oceanica is an “engineer” plant, able to:

a. capture CO2 in their praterias that act even more powerful than forests (blue carbon)
b. purify water
c. protect the coast from erosion and sediments creating big reefs
d.bring animals habitats



In these plan views it is possible to observe in more detail the intervention in the 3 main points:

-Intervention 1: Resilient Flooding Park and Resilient Cultivated Area (towards San Desiderio)

Due to this possible connection to the Richelie Fort and its beautiful landscape of mountainous area and open space, this site has been selected as a possible resilient area. The flooding channels and the sumergible furniture allow the possibility of flooding without risk of destruction of the proposed infrastructure, which is simple and strong.

Vegetacion oriented to proposals of purification is included in order to counteract the water pollution due to the urbanization process.

Bioengineered techniques are also part of the strategy, oriented to protect the terrain agaisnt erosion and sedimentation phenomena.

- Intervention 2: Interactive Stream Leisure Space (Riverside along Borgoratti Sport Area and Garden)

Current presence of a cultivated area has inspired the development of a resilient cultivated space, where the community can be part of the landscape also in a productive way and having awareness of the importance of the resilient concept.

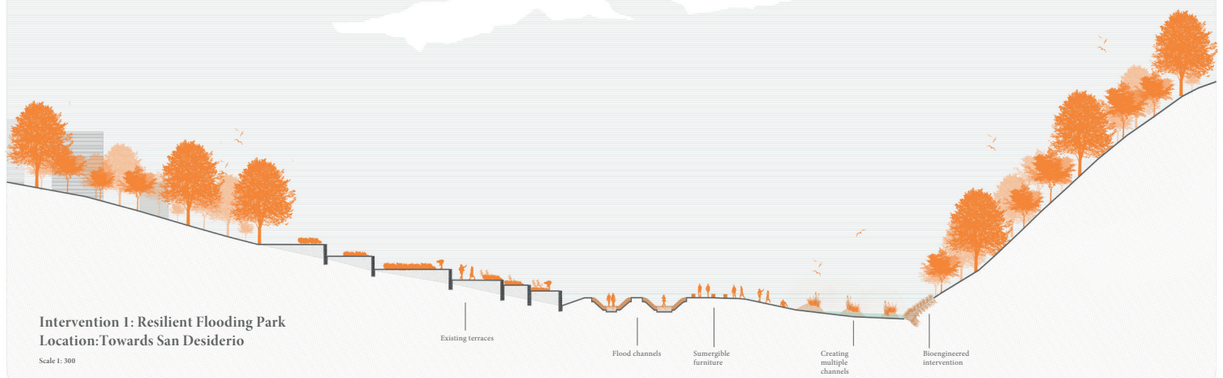
- Intervention 3: Modules _ Scogli, Small and Large Floating Island, Floating Spheres (in the Posidonia scattered area)

Different ways of intervention through the same module, allowing different social activities according to the depth. Starting from the Scogli that imitates the scogli configuration and let people to be in the sea but closer to the shore, just for relaxing or fishing, in this case Posidonia is not included because in this area there is an algae which does not have an interrelation with the Posidonia.

Small and Large Floating Islands for adventurous people, that like swimming, kayaking and diving or for motivational therapy through nature (thalasso therapy). At the same time, under these floating islands there will be calcarenitic stone modules with Posidonia and the traditional trasnplanting method inside the shelter space created by the modules.

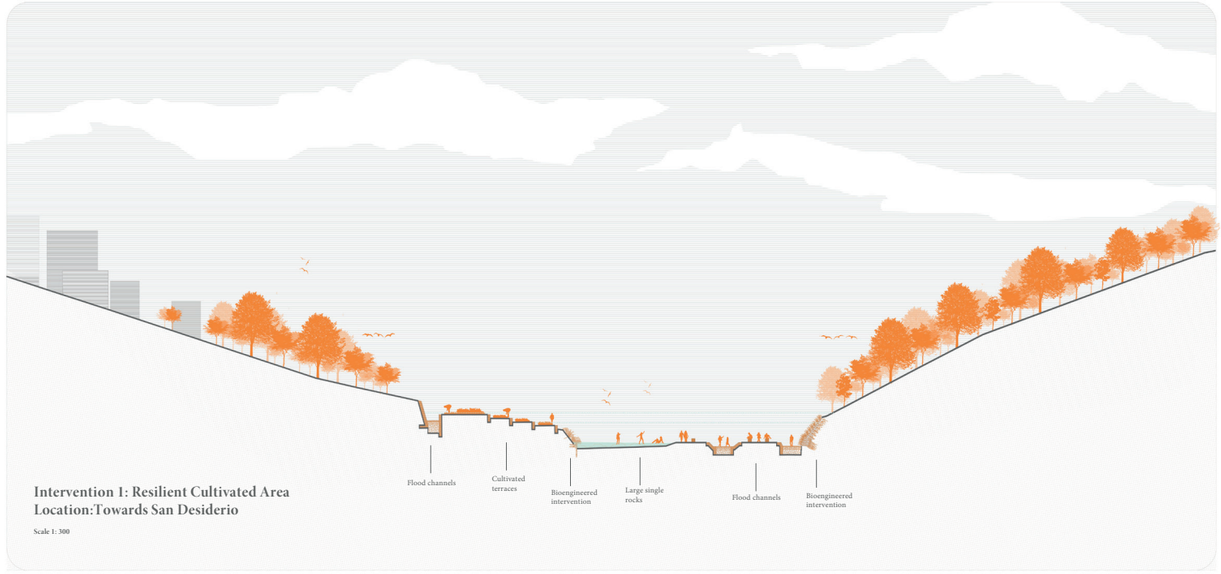
Finally, the Floating Spheres is a way of enjoying the landscape from a visual point of view, creating a kind of "seamark", which also draws attention to the ecological importance of this aquatic plant.
Children from the Istituto Giannina Gaslini hospital could be able to contemplate the landscape from their windows, perhaps bringing a little joy despite their situation.

Sections - Interventions along the Stream



Intervention 1: Resilient Flooding Park
Location:Towards San Desiderio

Scale 1: 300



Intervention 1: Resilient Cultivated Area
Location:Towards San Desiderio

Scale 1: 300

Intervention 2: Interactive Stream Leisure Space
Location: Riverside along Borgoratti Sport Area and Garden

Scale 1: 600

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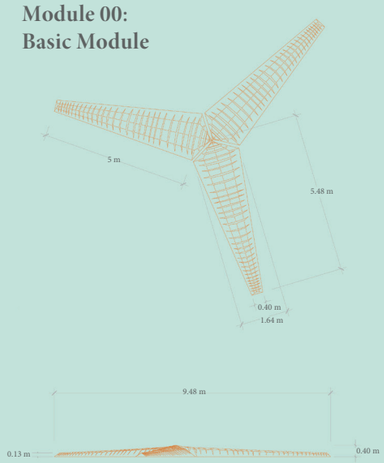
Thesis Project_ *Resilient Waterscapes in Genoa. From the Sturla Stream to the Ligurian Sea_***Advisor:** *Chiara Gerold_***Student:** *Paola Alejandra Aguilar Sánchez_940502*

In the Stream...

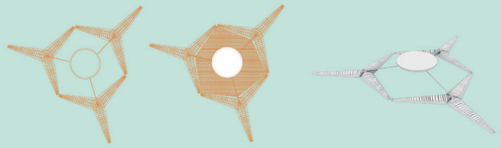
Nature based solutions along the stream

Modules for Posidonia oceanica

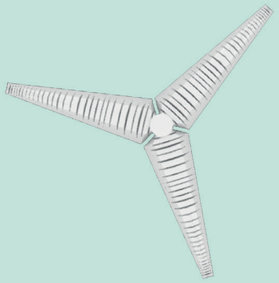
Module 00:
Basic Module

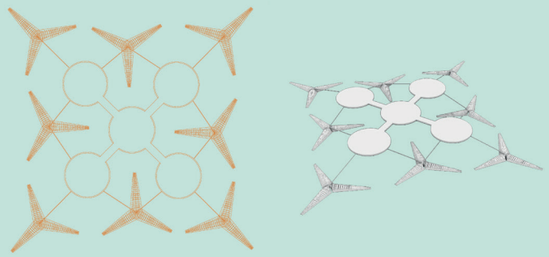


Module 01: Scogli



Module 02: Small Floating Island





Module 03: Large Floating Island

Module 04: Floating Spheres

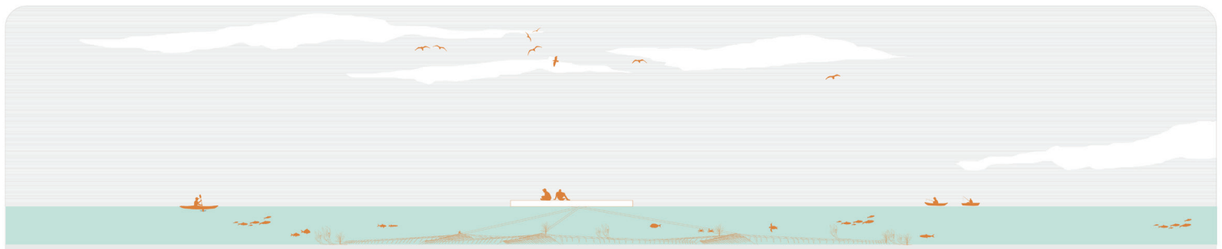
There will be a basic module that originates the other possibilities. According to the different configurations, four main modules can be proposed:

Module 01. Scogli
Module 02: Small Floating Island
Module 03: Large Floating Island
Module 04:Floating Spheres

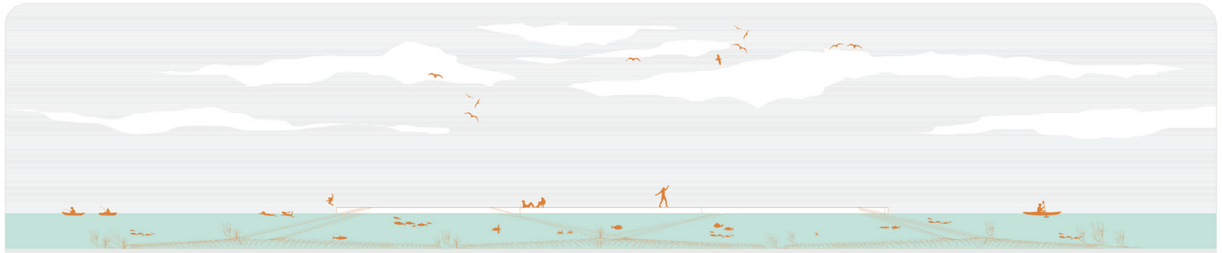
Sections - Posidonia oceanica Modules

General Section
Scale 1: 1000

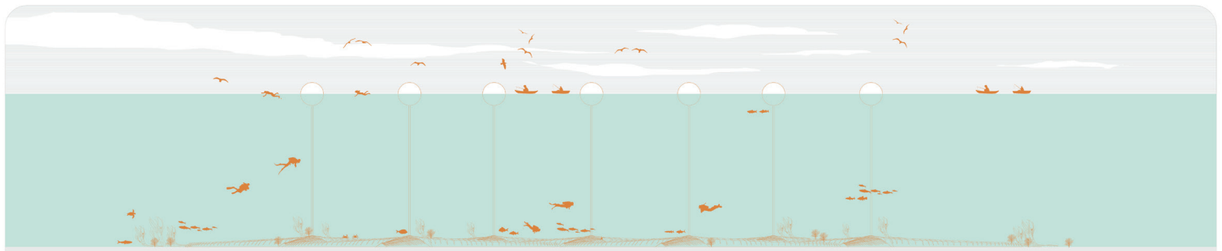
Module 01: Scogli
Scale 1: 150



Module 02: Small Floating Island
Scale 1: 150



Module 03: Large Floating Island
Scale 1: 150



Module 04: Floating Spheres
Scale 1: 150

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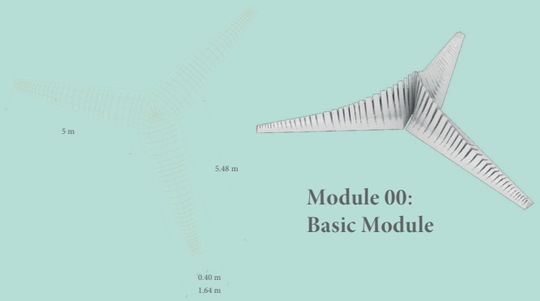
***Thesis Project**_Resilient Waterscapes in Genoa: From the Sturla Stream to the Ligurian Sea_**Advisor:**Chiara Geroldi_**Student:** Paola Alejandra Aguilar Sanchez_ 940502*

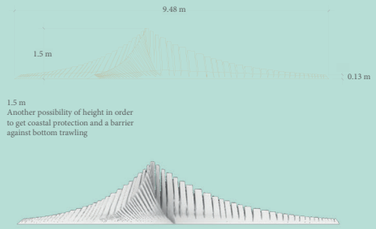
In the Sea...

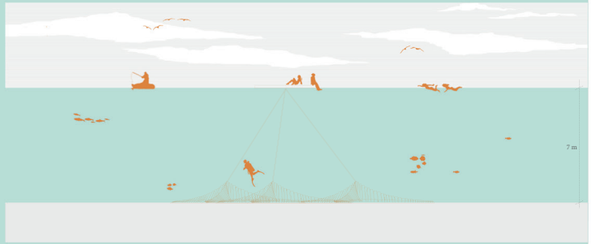
Ecological and Social activities surrounding the Posidonia Modules

Module for Protection of the coast from the waves

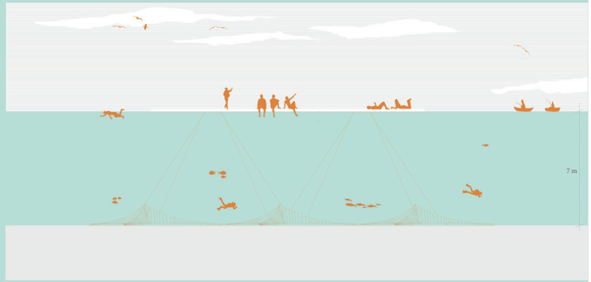


Module 00: Basic Module

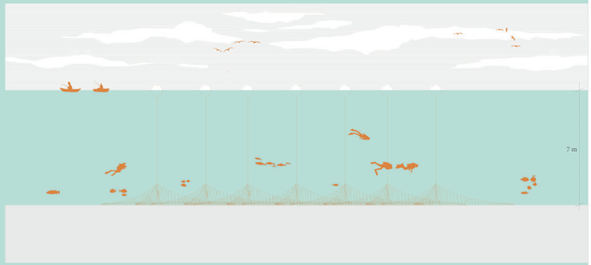




Module 02: Small Floating Island (1.5 m height)



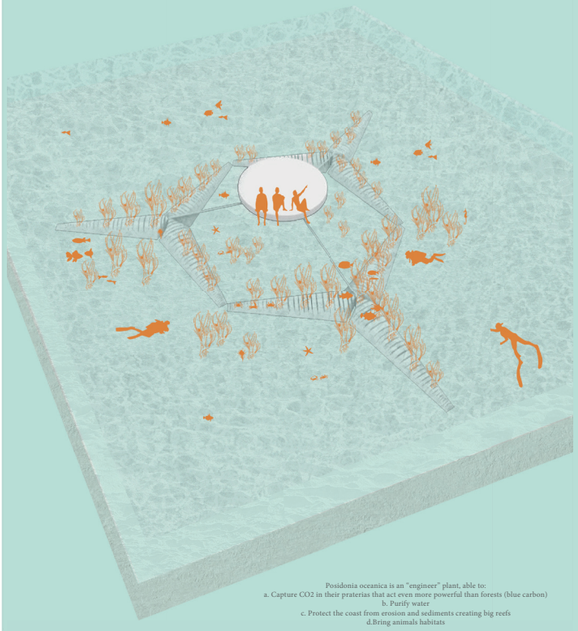
Module 03: Large Floating Island (1.5 m height)



Module 04: Floating Spheres (1.5 m height)

Living Ecosystem

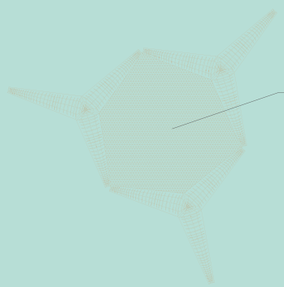
Improvement of a deteriorated area



Posidonia oceanica is an "engineer" plant, able to:
a. Capture CO2 in their praterias that act even more powerful than forests (blue carbon)
b. Purify water
c. Protect the coast from erosion and sediments creating big reefs
d.Bring animals habitats

Posidonia Benefits

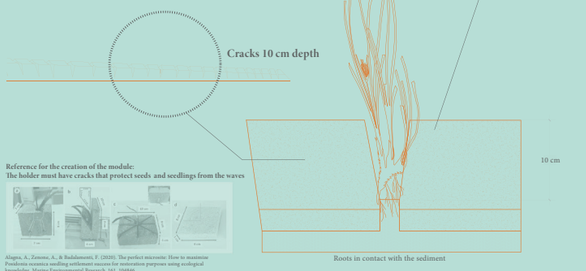
Grid



The sheltered space created among modules will be used as an area for traditional transplanting method,using coconut fiber and a grid made of metal

Material

Modules made of **Calcarenitic stone**, present in the site. Moreover, **calcic carbonate** is part of many organisms, such as the **Calcareous sponges (Calcispongiae)**, source of inspiration for the creation of this module



Reference for the creation of the module:
The holder must have cracks that protect seeds and seedlings from the waves

Alagna, A., Zenone, A., & Badalamenti, F. (2020). The perfect microsite: How to maximize Posidonia oceanica seedling settlement success for restoration purposes using ecological knowledge. Marine Environmental Research, 161, 104846.

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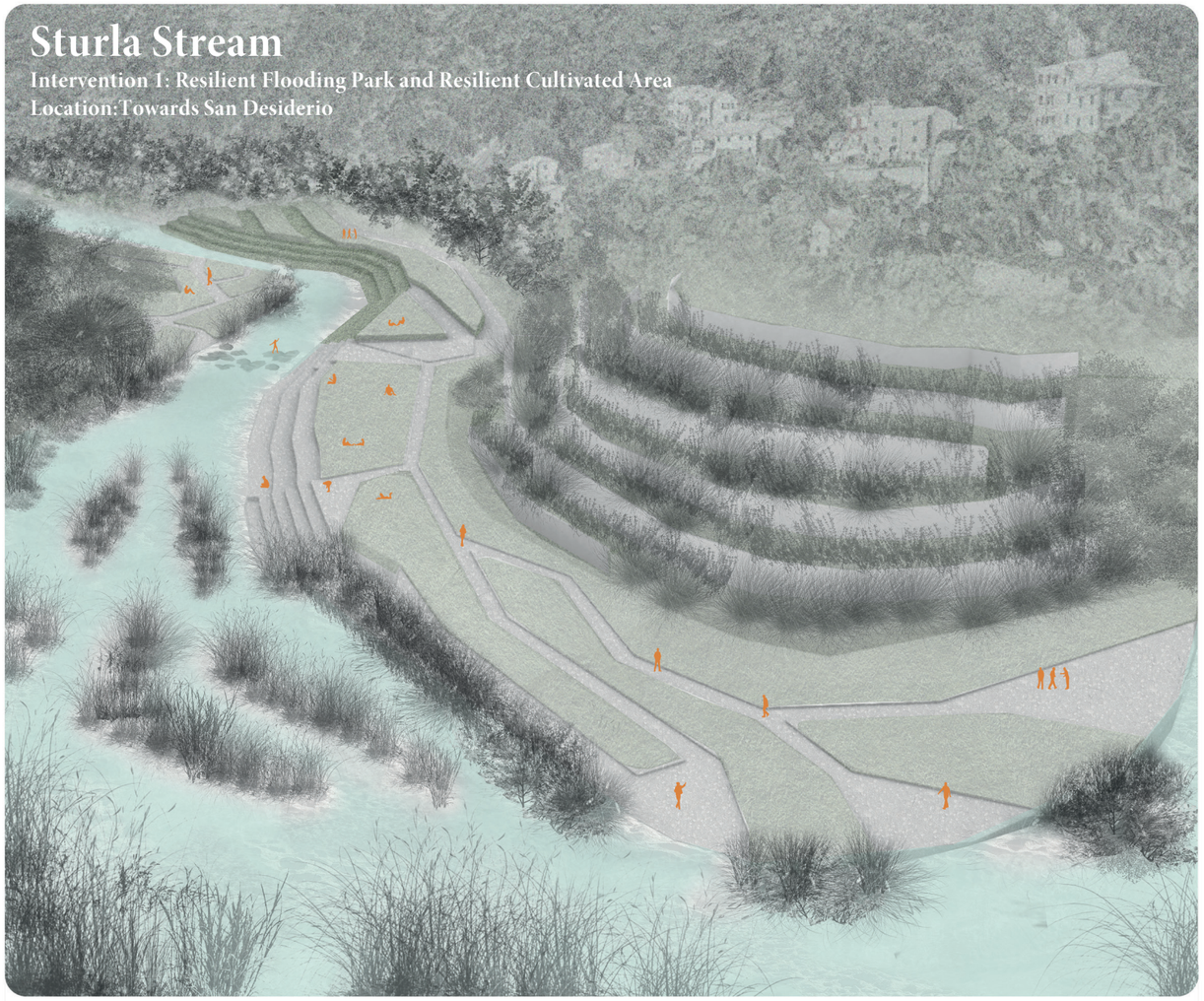
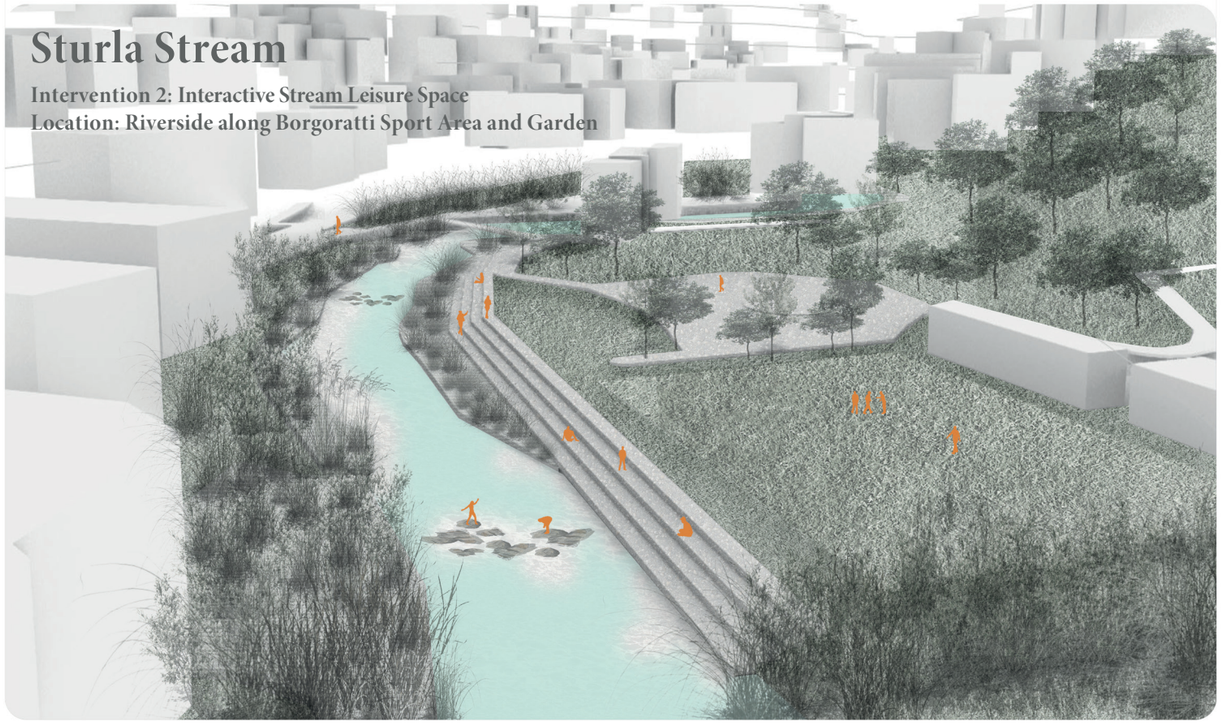
In order to achieve this purpose of Posidonia oceanica repopulation the researches of Badalamenti et al.(2020) has been of great importance in order to develop the module idea.

These modules will be made of calcarenitic stone, a material with good results in terms of Posidonia growing. The idea is to create a solid volume with many cracks that allow the placement of Posidonia seedlings. The shape has been inspired by the book of Artforms in nature (E.Haeckel,) specifically in the amazing shapes that calcareous sponges follow, which are made of calcic carbonate.

Inside the configuration of modules, there is a shelter space that can be the area for the traditional transplanting method of Posidonia, through a metal grid and coconut fiber.

Moreover,a module for protection of the coast from waves is also proposed. The difference compared to the original module will be its height (1.5 m) in its upper part.

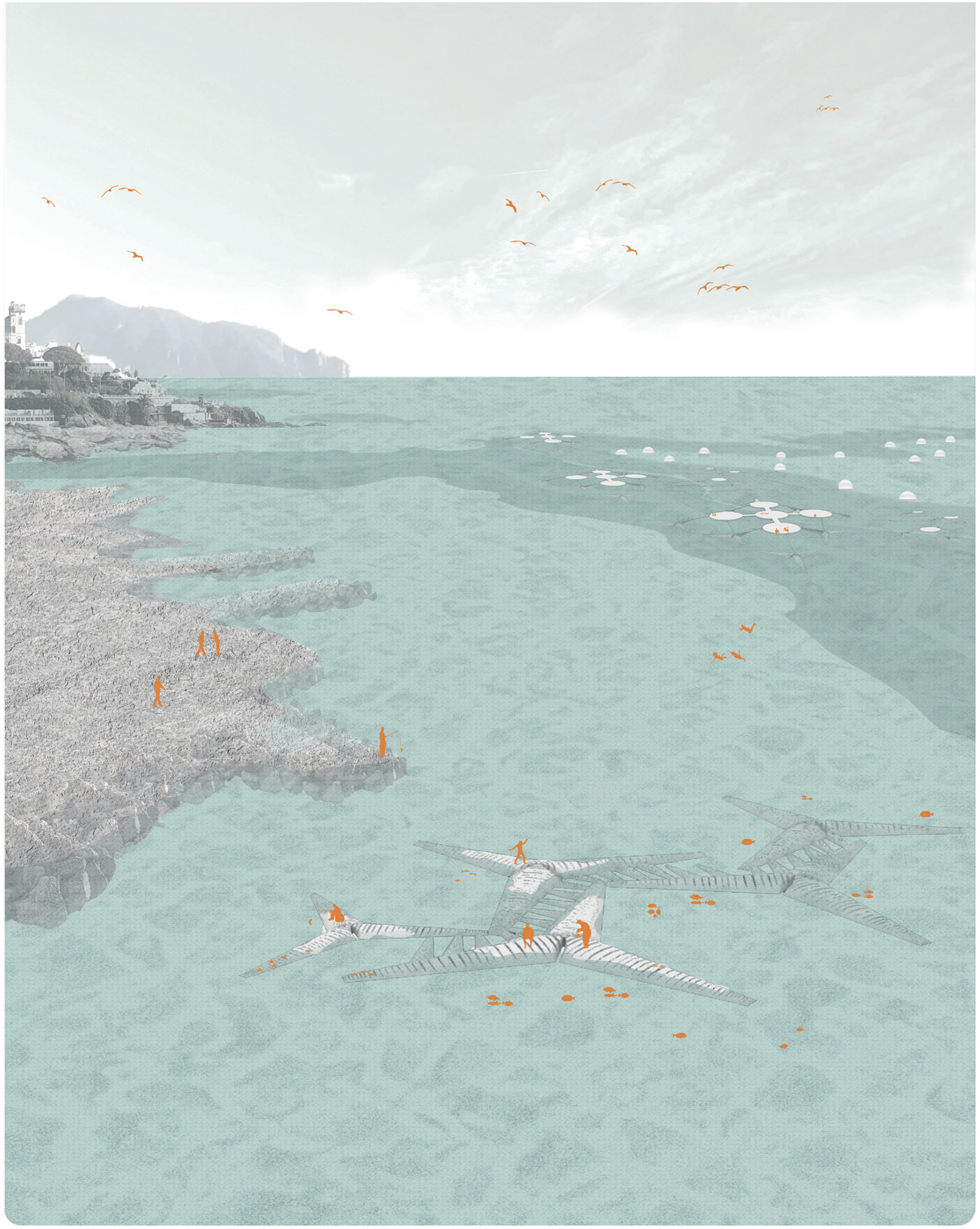




In the Stream...

Ligurian Sea

Intervention 3: Modules _ Scogli, Small and Large Floating Island, Floating Spheres
Location: Posidonia scattered area



In the Sea...

Conclusions

The sea is the reflection of our actions. Everything is going to have a result, so the problems that can be addressed within the stream will have an impact on the problems in the sea.

Moreover, closeness with this amazing waterscape has been always part of human life, for these reasons the proposal has searched to highlight how the last step of Posidonia oceanica repopulation is part of a previous work.
Environmental enhancement, but also socio-economical activities can be consequence of this intervention.From the poetical point of view, it could inspire young and elderly people about landscape resilience against adversity.

Among the proposal positive results, can be mentioned:

-Protection of infrastructure and properties from sea level rise risk, flooding and fires.
-Protection of an ecological corridor as the Sturla Stream, home of many species of birds among others.
-Creation of public spaces linked to the aquatic ecosystems.
-Use of nature based solutions (NBS) along the river, as a way of protecting the posidonia health in the sea
-Regeneration of posidonia prairies in front of the beach.Subsequently, challenges can be counteract by this fantastic aquatic plant.

Interventions along the stream are a vital step in order to reach real changes in the sea. Stream and Sea are an interconnected system where the acts carried out uphill affect what is happening downhill.

The proposal pretends social awarenees of this fact and the introduction of the resilient concept in these wonderful waterscapes. In conclusion, the environmental situation would improve directly, as well as indirectly boost the social and economic condition of the inhabitants of Sturla, through sites that allow the contemplation of the landscape and the development of activities of benefit to the community. The proposal is only one possible suggestion to encourage more resilient waterscapes.

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