THERE WILL BE FLOOD

Resilient architecture for sea level rise

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Department of Architecture and Civil Engineering

Examiner: Emilio da Cruz Brandao
Supervisor: Shea Hagy
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ABSTRACT

Climate change is one of the biggest challenges of the modern world. This master thesis focuses on the threats related to the marine environment: sea level rise and ocean degradation. Due to those ocean changes, most of the coastal communities are exposed to huge risks. The main research question of the thesis is: how can architecture strengthen the resilience of coastal communities and reduce their vulnerabilities?

The author's research is based on the environmental reports produced by the Intergovernmental Panel on Climate Change in order to map the global risks related to sea level rise and ocean degradation. The analysis of three case studies (Rotterdam, Netherlads, Staten Island, NY, USA and Mahé, Seychelles), provides examples of existing patterns in coastal defense. The research uses the theory of resilience and regenerative design to create a framework of resilient architecture.

The objective of the thesis is to propose a set of design strategies for resilient architecture in the coastal environment. Those guidelines are recommended for any communities struggling with coastal hazards and could be implemented globally.

The design strategies are later illustrated using the concept of the Blue Education Center developed by the author for Mahé. The proposal has a diagrammatic framework and focuses on programmatic issues, instead of the appearance of the building or technical solutions.

The thesis is a contribution to the on-going discussion around coastal architecture and the resilience of coastal communities. It underlines the importance of an interdisciplinary approach and the value of research on the constantly changing coastal environment.

KEYWORDS

sea level rise
ocean degradation
coastal communities
resilience
regenerative design

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CONTENTS

01

INTRODUCTION

PERSONAL BACKGROUND

Olga Mazurek

Bachelor of Architecture:

Warsaw University of Technology

2012 - 2016

Master of Architecture:

Chalmers University of Technology

2018 - 2020

I was born and raised in Warsaw, with the closest coast more than 300 km from my home. Yet somehow the sea has always been a big part of my life. I started sailing when I was 7. I learned how to scuba dive when I was 14. I love swimming. I consider sailing across the Atlantic and the Pacific Ocean my biggest achievement so far. Most of my travels are based around spending time close to the water. I moved to Gothenburg because of the coast and archipelago.

Inevitably, during my education I tried to work on projects related to the water. But it was not until I read about the "Sink or Swim: Designing for a Sea Change" exhibition, followed by Iwan's Baan TED talk "Ingenious Homes in Unexpected Places", that I became interested in human resilience in extreme environments.

This master's thesis is a result of huge respect for the maritime environment and my personal feeling of responsibility for taking care of it. Human activity is destroying life above and under water and it is time to take positive action to protect naval life. So that it can keep bringing us joy rather than destruction.

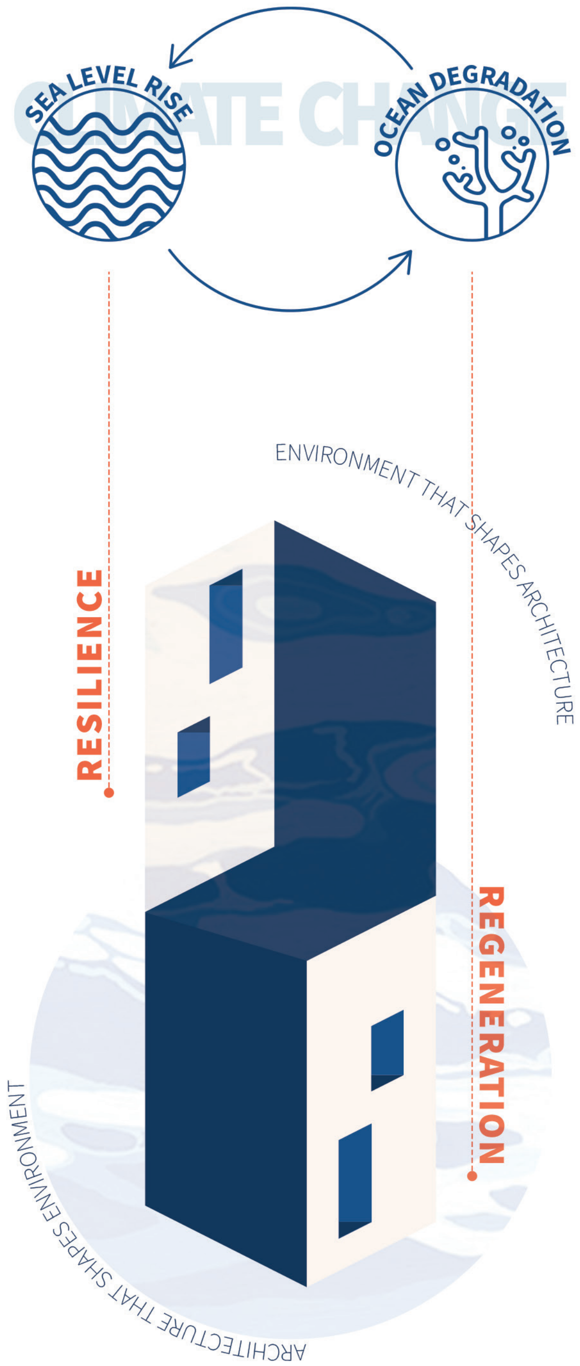


Figure 1.1. Manifesto

BACKGROUND AND DELIMITATION

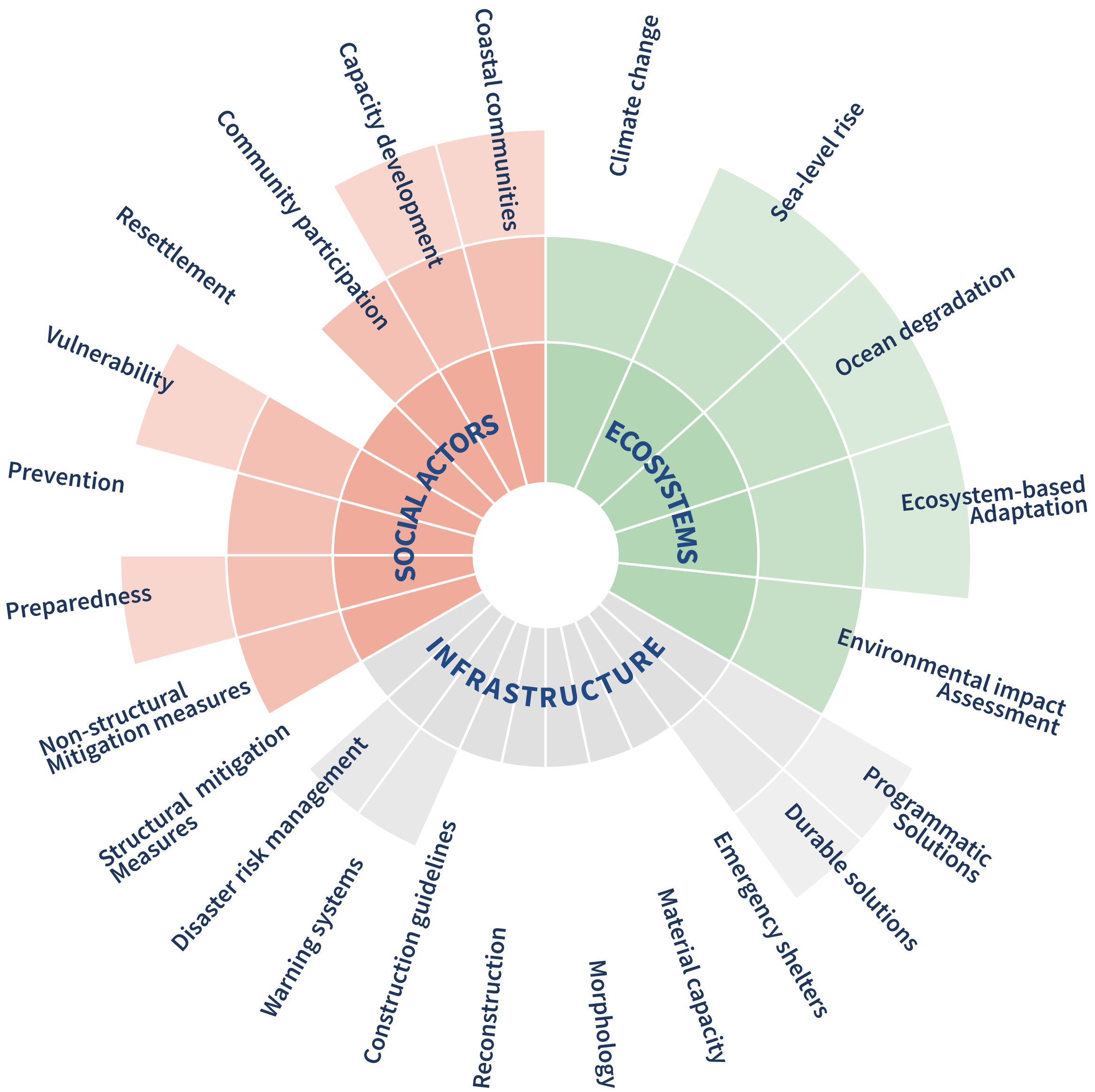


Figure 1.2. Delimitation diagram

About 40% of the world's population lives less than 100 km from the coast (Magnan et al. 2019). The marine environment has a big impact on our daily lives, yet human actions are causing its deterioration. Continuous global warming and lack of plans to mitigate climate change is a major cause of sea level rise and ocean degradation that result in the intensification of coastal hazards (Oppenheimer et al. 2019).

At the same time, every year more people move to the coast, negatively impacting ecosystems and creating vulnerable communities (Magnan et al. 2019).

This rising exposure and frequent hazards are a combination that changes the potential risks into disasters (Davis, Krimgold, Thompson, 2015).

Rising numbers of vulnerable communities across the world and forceful hazards require global effort in developing programs of disaster preparedness, disaster relief, post-disaster reconstruction, and prevention (Davis, Krimgold, Thompson, 2015).

Disaster Risk Reduction (DRR) is a concept of reducing the exposure to the hazards by building a culture of safety, increasing local capacities to cope with extreme events and improving preparedness for adverse situations (ASF-Int., 2012).

In general, it may vary according to local context and it combines four phases of planning. First, pre-disaster phase, focuses on planning, training and raising awareness to increase preparedness and reduce exposure. Second, immediate relief period is an emergency phase that happens directly after the hazardous event and aims at satisfying basic needs, such as shelter, food and freshwater, and medical supplies for casualties. Third and fourth, are long-term rehabilitation period and reconstruction to assess damage and rebuild, and enable local processes and growth (Davis, Krimgold, Thompson, 2015).

The key to disaster management is understanding the social structures of local communities (ASF-Int., 2012). Local and indigenous knowledge is one of the three components contributing to the framework of local DRR. Additionally, participation of local communities in the process of recovery improves the effectiveness and results of post-disaster recovery (UN Development Programme, 2020).

However, this thesis is not about risk management, emergency shelters or the recovery process and does not include community participation. The research focuses on how to increase the preparedness of coastal communities against hazards by restoring local ecosystems.

The first step in DRR is understanding the cause, therefore the purpose of this master's thesis is to analyze the risks related to sea level rise and ocean degradation and how they influence the coastal communities in three sectors: natural environment, social structures and economic status.

The objective of the thesis is to develop design strategies for resilient and regenerative architecture, necessary to create strong neighborhoods and restore the balance between the built and the natural environment and human activities. The strategies build up preparedness of the communities, therefore the thesis is in the framework of the first phase of DRR.

Subsequently, the design proposal is a generic and systemic model that illustrates those strategies with the project of the Blue Education Center for Seychelles. The design presents resilient solutions and regenerative technologies that could be implemented in other coastal communities that are also vulnerable to marine changes.

The focus of the research is on two United Nations Sustainable Development Goals (UNSDG): Climate Action and Life Below Water.

The process of preparing the thesis was disturbed midway through and the framework of the research had to be changed. Almost half of the research was supposed to be carried out during a field-study trip to Seychelles to analyze the specific context of one of the Small Island Developing States. However, due to the COVID-19 pandemic the trip did not happen and the design is based on assumptions about the context and desk research based on reports and academic papers.

RESEARCH QUESTION

How can architecture strengthen the resilience of coastal communities to sea level rise and reduce their vulnerabilities?

METHODS

This master's thesis starts with the analysis of global challenge of SLR and ocean degradation to extract the environmental risks. Next identifies existing patterns and responds to the those risks, by analysing three case studies.

The comparison of three different case studies allows us to extract design guidelines for the rising sea level.

The last part illustrates those guidelines by designing for one of those case studies.

Research for design focuses on three areas: background of environmental changes and future scenarios, existing trends and patterns of responding to sea level rise and ocean degradation, and social connections and possibilities for cooperation.

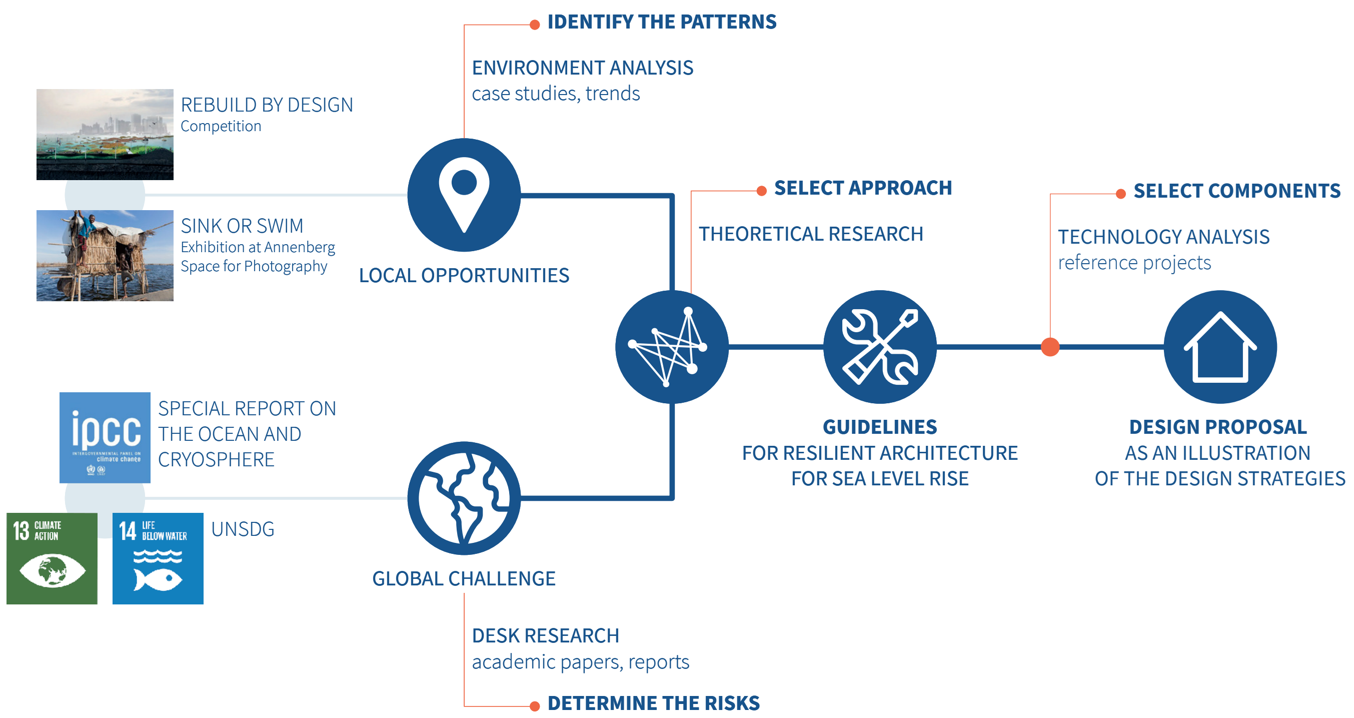


Figure 1.3. Research for Design

THEORY

The thesis explores the theory of resilience as a response to the complex net of environmental risks. Other theories, such as adaptive decision making and vernacular architecture, also support resilience.

The concept of regenerative design is an attempt to strengthen resilience and reduce environmental risks in the future. The research is supported by the benefits of polycultural structures and socio-ecological systems with a big influence of ecological design.

The key information regarding sea level rise and ocean degradation comes from the *Special Report on the Ocean and Cryosphere in a Changing Climate* (SROCC) prepared by the Intergovernmental Panel on Climate Change (IPCC). The report gathers the latest scientific research and was written as a collaborative work of more than 100 scientists from 30 countries.

READING INSTRUCTIONS

Chapter 1 includes the research question and explains the background and motivation behind choosing the research topic.

Chapters 2 collects the research about the global challenge and connects it with the risks for coastal communities.

Chapter 3 present the analysis of three case studies.

Chapters 4 introduces the theoretical background of resilience response and supporting theories.

Chapter 5 extracts the research from chapters 2, 3, 4 and proposes design strategies for resilient architecture.

Chapter 8 explains the importance of local communities' participation during the implementation of design strategies.

Chapters 7 is an illustration of the design strategies with a proposal of the Blue Education Center.

Chapter 8 sums up the research and presents the outcome of the thesis. It also proposes follow-up questions to develop the discussion.

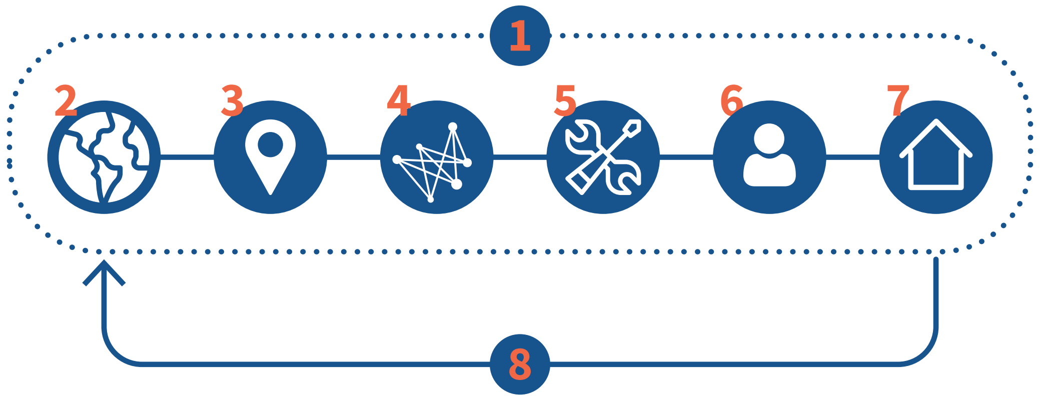


Figure 1.4. Reading instruction

ABBREVIATIONS

This master's thesis is mainly based on reports created by the IPCC and therefore for better understanding of the process of the research it is important to know some of the names and acronyms used in their reports beforehand.

SLR - Sea Level Rise. The change in the height of the sea surface, both locally and globally.

GMSL - Global Mean Sea Level. The average level of the surface of the earth's seawater (the point from which elevation is usually measured). The GMSL excludes tides and local sea level change.

IPCC - The Intergovernmental Panel on Climate Change. UN's body uniting scientists from all countries to cooperate on research on climate change.

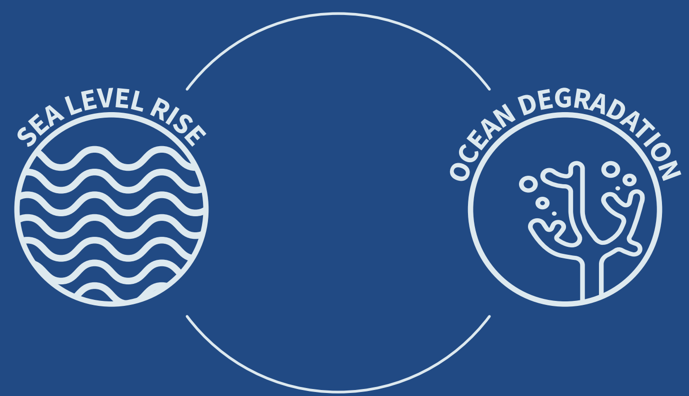
CMIP - Coupled Model Intercomparison Project. The Program to simulate and archive climate models based on knowledge shared between modelling groups around the world. This master's thesis uses **CMIP5**, which is a model based on a data set that includes projections using the RCPs.

RCP - Representative Concentration Pathway. One of many future scenarios created by analyzing historical and future environmental changes over time.

Because of time restrictions, this thesis is based on RCP 2.6, which represents the case of low greenhouse emission and a high mitigation process in the future, and RCP 8.5, which represents a high greenhouse gas emissions scenario in the absence of policies to combat climate change.

02

OCEAN CHANGE



Ocean changes are one of the most critical challenges related to global warming. The ocean plays a fundamental role in shaping the climate by accumulation and redistribution of carbon dioxide. All ecosystems depend, directly or indirectly, on the ocean. It is a crucial part of human lives, including food and freshwater, renewable energy, health and well-being, cultural heritage and trade and transport (IPCC, 2019).

In its 2019 *Special Report on the Ocean and Cryosphere in a Changing Climate*, IPCC used a Coupled Model Intercomparison Project (CMIP5) based on two Representative Concentration Pathways (RCP), RCP 2.6 and RCP 8.5, to create projections for future ocean changes. RCP 2.6 uses data assuming a completed mitigation process and reducing the emission of greenhouse gases. RCP 8.5 is a scenario in which the current emission rate consistently grows and mitigation policies are not introduced. Comparing two scenarios gives a perspective on the difference we can make by mitigating climate change.

That difference will have an enormous impact on 11% of the global population, living in areas of Low-Lying Islands and Coasts (LLIC), that are already struggling with storms, flooding, ocean heat waves or tropical cyclones (Magnan et al, 2019).

LLIC are characterized by wide cultural diversity: from coastal cities and megacities, such as New York, Tokyo or Lagos, to Small Island Developing States (SIDS), such as Kiribati, Seychelles or Barbados.

Despite cultural, economic and climatic differences, they share a high level of vulnerability regarding sea level rise and ocean changes. Without future adaptation interventions, cascading risks will intensify, causing huge damages to the people, infrastructure and natural ecosystems (Magnan et al, 2019).

SIDS, are not only the most vulnerable ones but often the least prepared at the same time. They often experience similar challenges, such as small but growing populations, limited resources, remote location, vulnerability to external shocks and excessive dependence on international trade (Magnan et al, 2019).

Their societal challenges will combine with climate risks increasing the damages. For example, in 2015 tropical cyclone Pam devastated Vanuatu, a Pacific island country, creating economic loss of nearly 60% of their GDP (Magnan et al, 2019). Moreover, for most SIDS their economic development is ocean-based and it will decline with ongoing ocean degradation.

For some countries, adaptation responses might not be enough as they are already struggling with rising sea level and land loss. The lowest atolls, such as Kiribati or Tuvalu, two central Pacific archipelagos, prepare for retreat, risking their sovereignty, to reduce the trauma of displacement (Mcnamara, Gibson, 2009).

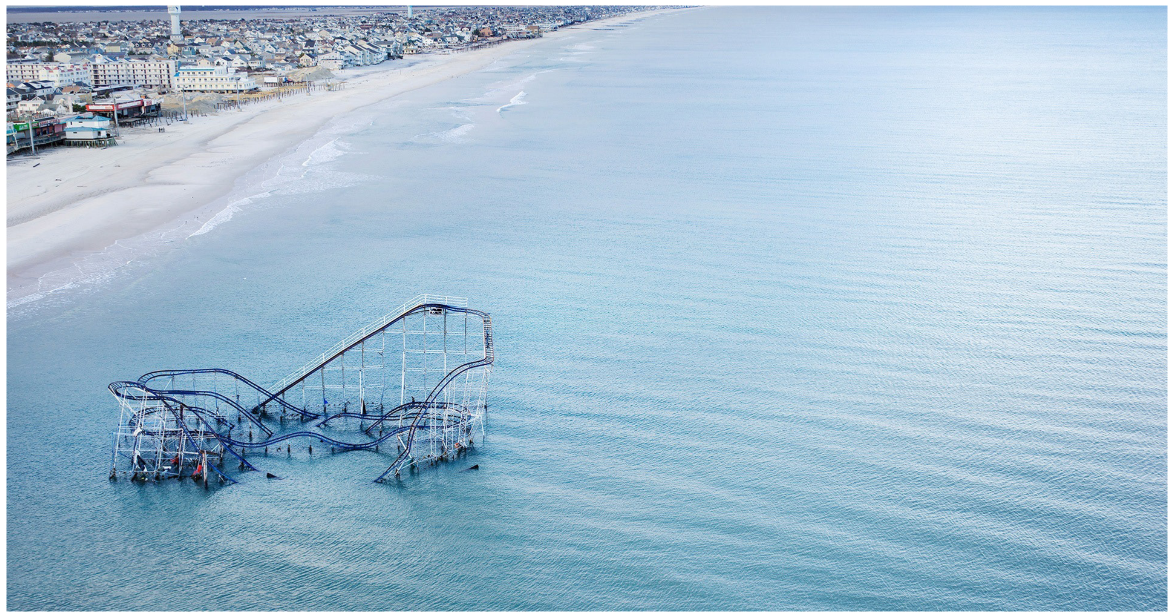


Figure 2.1. Wilkes, S., 2012, Roller coaster after Hurricane Sandy - Seaside Heights, New Jersey

SEA LEVEL RISE

The Global Mean Sea Level (GMSL) is rising 3.6 mm per year at the moment with certain predictions to accelerate up to 9 mm per year by 2100 if we mitigate climate changes and reduce the greenhouse emissions, or up to 20 mm per year if we do not (Oppenheimer et al, 2019). The predictions for the next 30 years show that by 2050 the GMSL will rise between 240 mm and 320 mm on average.

As the situation might seem hopeless already, it is important to understand that the extent of the changes is still up to our actions. Figure 2.2 shows the predicted differences in GMSL under two scenarios. Because the predictions are based on historic and ongoing patterns, the forecast is certain up to 2100 and highly uncertain in the long term (Oppenheimer et al, 2019).

As the GMSL is steadily rising, we can predict further changes in regional or local sea level rise, that could vary up to 30% compared to GMSL. Depending on the land ice loss, variations in ocean warming and circulation, it is expected that warmer regions will be influenced faster and to a greater degree than those with a cooler climate (Oppenheimer et al, 2019).

GMSL is also one of the contributors to extreme sea level rise events, such as storms, distance swells or tropical cyclones (Oppenheimer et al, 2019). Those are the biggest challenges for the coastal communities as the force and the velocity of those events are usually stronger with time and often harder to predict. In vulnerable places, it is expected that those extreme events will increase under all scenarios.

The SLR challenges that might look like a distant future for us, are already impacting SIDS. Regular flooding and land loss are already influencing lives in countries like Maldives or Marshall Islands. Low-lying and remote islands are highly vulnerable to both extreme events and slow onset changes related to the ocean state and most of them will exceed their adaptation limits beyond 2100, under all RCPs (Oppenheimer et al, 2019).

The coastal communities are exposed and vulnerable, additionally, by settlement patterns and loss of the indigenous and local knowledge and other human activities that negatively influence the adaptive capacity.

An example of such activities is the trimming of mangroves by coastal home-owners. The complicated root system of the trees holds onto sediments. Cutting them down increases erosion and removes natural wave protection. Therefore trimming them not only creates a more exposed environment and sensitive architecture but increases the effects of SLR such as land loss .

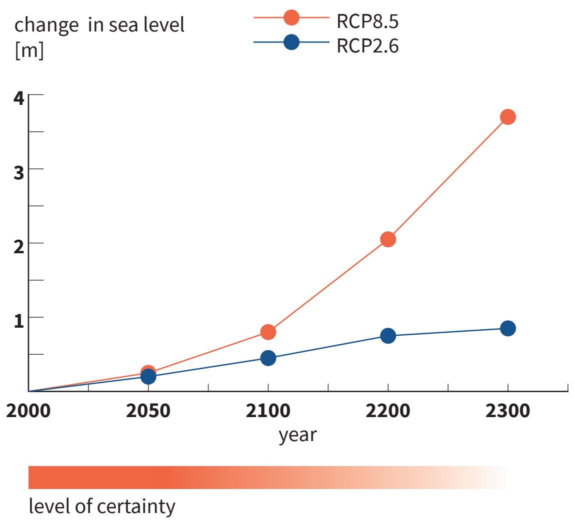


Figure 2.2. SLR projections, adapted from IPCC

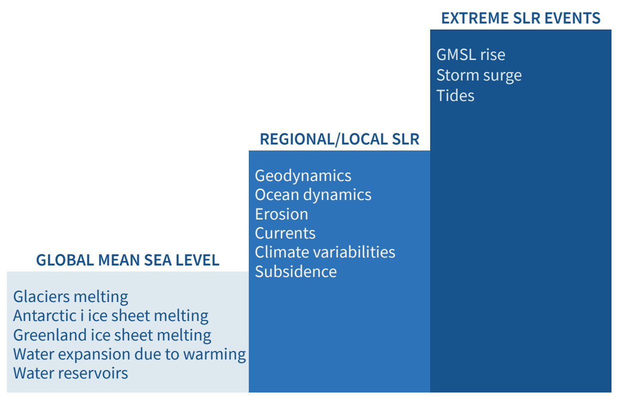


Figure 2.3. Changes related to SLR and its main reasons

DEGRADATION OF MARINE ECOSYSTEMS

The biggest threat to marine life and coastal ecosystems is global warming. Due to increased carbon uptake from the atmosphere, the ocean is warming up, resulting in stratification, oxygen loss and increased acidification. The environmental changes impact natural processes of marine ecosystems, interfere with nutrient cycles and obstruct carbon cycles, which are major drivers shaping climate conditions (Bindoff et al, 2019).

Coastal ecosystems, such as mangrove forests or salt marshes, are highly affected by SLR and extreme events, such as storms and tropical cyclones. At the same time, those ecosystems play an important role in protecting the coasts. With the degradation of coastal environments, their capacity to adapt declines, making them more vulnerable (Bindoff et al, 2019). Additionally, coastal ecosystems are impacted by human activities both on land and water, such as extensive coastal urbanization, human-induced habitat degradation and increased pollution (Oppenheimer et al, 2019).

Slow-onset ocean changes and sea level rise create a chain reaction of risks, directly threatening coastal communities. Global warming is causing increased carbon uptake by the ocean, which results in higher acidity of the water. High water temperature is a direct cause of coral bleaching, as it loses the symbiotic algae, the zooxanthellae, that covers its tissues. Bleached coral colonies have a lower capacity of reproduction and are more vulnerable to other threats. Increased acidity of the seawater prevents corals from building their calcium carbonate skeletons and in severe acidification it could lead to damages of the existing skeletons and the destruction of already existing coral reefs (Smithsonian NMNH). That leads to an overall degradation of the habitat that coral structures create for many ocean species, both in terms of food and shelter. That disturbance of the natural ecosystem, accelerated by stratification, limits the ocean's productivity and reduces the overall fish stock. Most of the coastal communities, especially SIDS, depend on marine ecosystems services and the fishing sector is their main source of income, both in terms of private income and national export product. Moreover, for many SIDS fish is the main source of protein in their everyday diet and lack of it could indirectly lead to deterioration of health (Bindoff et al, 2019).

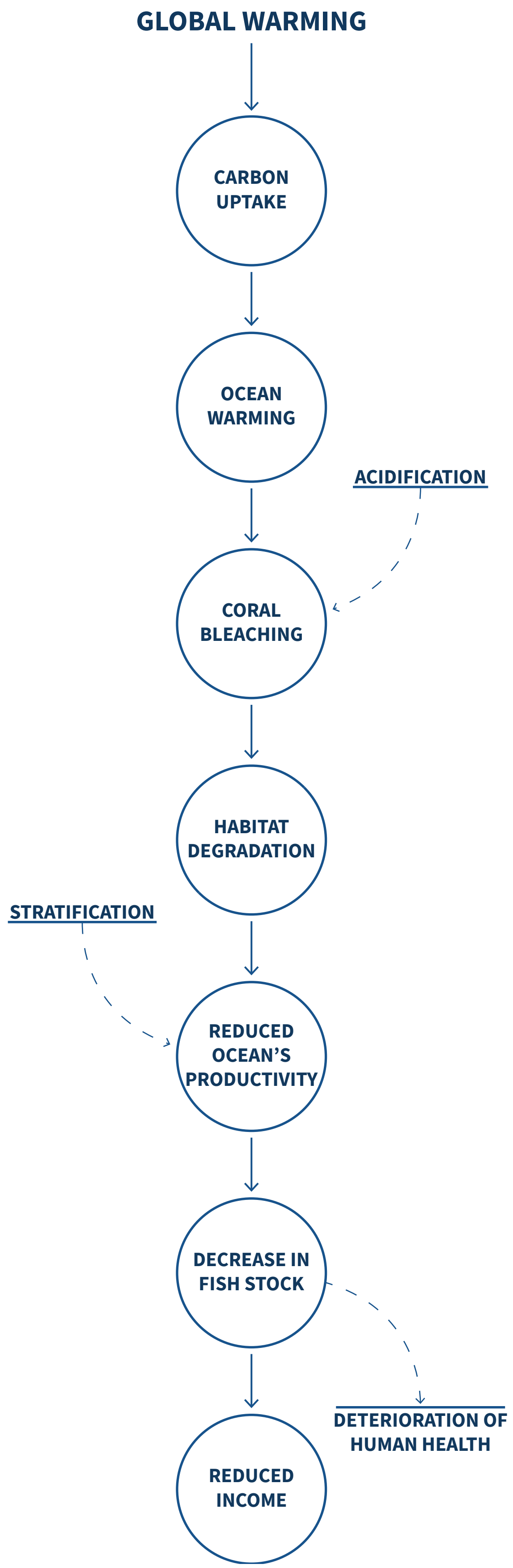


Figure 2.4. Example of the ocean warming chain reaction

OCEAN CHANGE AND RISKS

The map shows interconnections between consequences of climate changes and the impact they have on the surrounding environment, referred to as the risks. Some factors are both the cause and the implication in the chain reaction.

The risks are divided into three groups: those related to the natural ecosystems, those linked with humans and those associated with the economy.

The lines show the direction of the action. "+" and "-" show if the factor is increasing or decreasing compared to the cause. The continuous line implies direct impact and the dashed line indicates indirect impact.

Ecological risks (green) include all risks related to the natural environment, animals, plants, fungi and protists. The danger relates both to their health, decrease in numbers and kinds.

- Flora
- Fauna

Economic risks (grey) include the capital lost due to the climate changes. It includes decrease in the income for some groups as well as expenses to recover damaged areas and infrastructure. This group also covers the budget for protection and adaptation.

- Income
- Infrastructure

Social risks (red) are those related to humans. Their health and well-being, culture, and activities and live-hoods.

- Activities
- Health

Factors in beige represent the non-climatic drivers that affect the system by reducing the capacity or increasing the hazards.

- Non-climatic

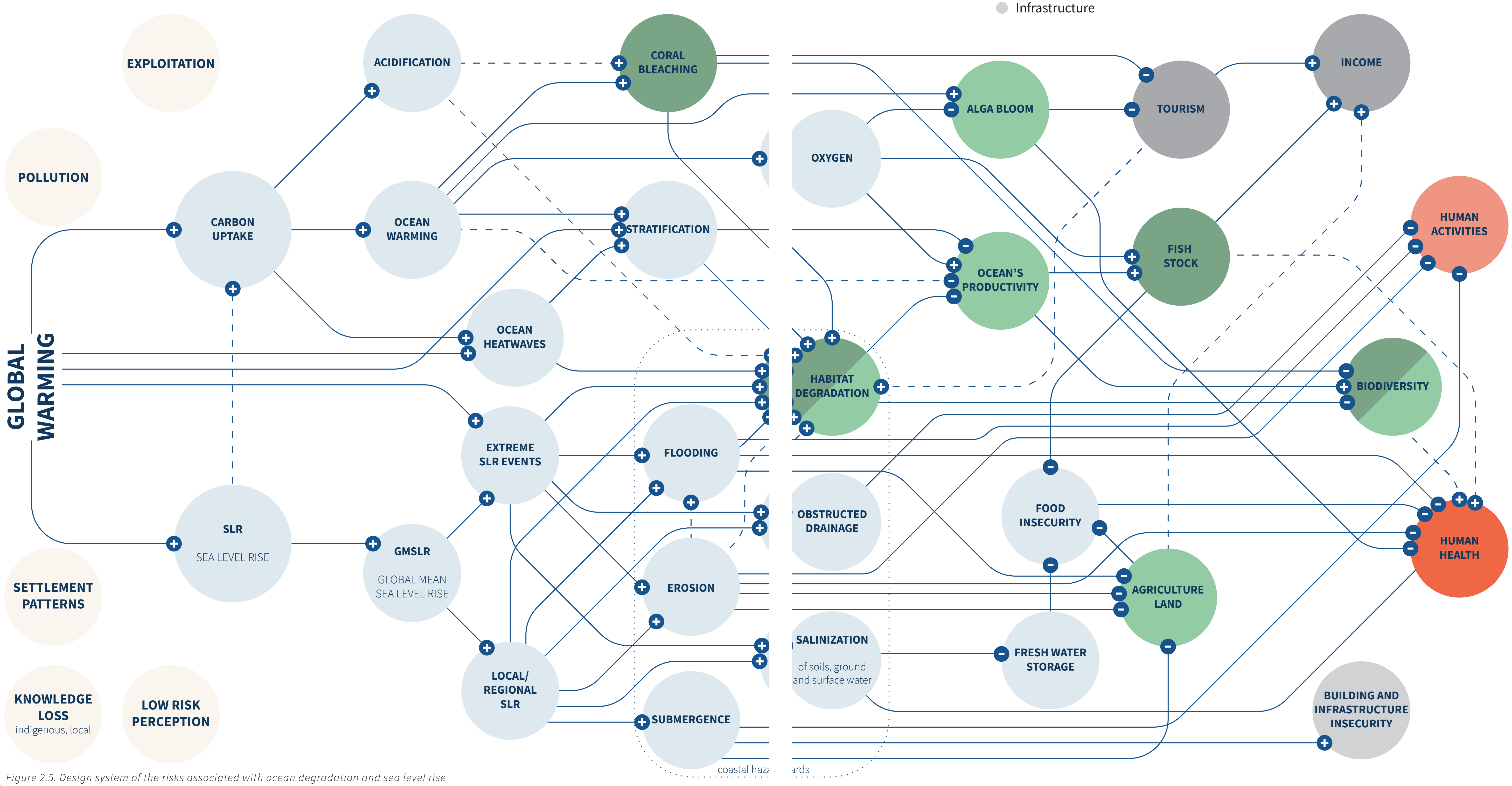


Figure 2.5. Design system of the risks associated with ocean degradation and sea level rise

03

COASTAL DEFENSE: CASE STUDIES

ROTTERDAM

Netherlands

Figure 3.1. Map of Rotterdam

326 km² (117 km² covered by water)

651 446 - population (4% of country's population)

3 087/km² - density

- *land area of Rotterdam*
- *land outside Rotterdam*
- *rivers and canals*

The Netherlands are cited as one of countries which is most adapted to sea level rise. Since the first prehistoric settlements, they have been trying to defend themselves against the rising sea and flooding from the rivers. Dutch history goes through adaptation plans and protection strategies to deal with a difficult, low-lying location (VanKoningsveld et al, 2008).

The biggest turning point came after the North Sea flood in 1953, resulting in the Delta Project. The project started as an attempt to reduce the vulnerable coastline by closing all sea inlets, except two entrances: to the Port of Rotterdam and the Port of Antwerp. It is still developing and globally changing the way of dealing with SLR (VanKoningsveld et al, 2008).

The construction of the closing gate was determined by research and historic sea rise. Future changes, except acceleration, were taken under consideration. The Delta Project prioritizes constant monitoring, data gathering and the value of research as the base for any developments. The latest Delta Programme (2019) highlights "Intensification of research into water and climate issues" as one of the three focus recommendations (Delta Programme, 2019)

The reason why the Netherlands are in the lead of working against SLR might be because of the early implementation of the top-down policy and the focus on an interdisciplinary approach, involving coastal engineers, urban planners, geologists, historians and physical geographers early on in the process.

1/3 of Rotterdam, the second biggest Dutch city, is covered by water and almost 90% of the land is below the sea level. Because of its strategical location 50 km from the North Sea on the river Rhine (Rhine–Meuse–Scheldt Delta) and because of the system of canals, it has developed as the largest port in Europe.

Even though technically it does not have a coast, the city is extremely vulnerable to the mean SLR and extreme SLR events that move up the river through Nieuwe Waterweg, a ship canal connecting the city and the North Sea (Kwadijk et al, 2010).

The city is filled with water management solutions, including "water parks" that work as storage ponds, and a stormwater discharge system, that sends the water from the streets to the river.

One of the city's proudest projects, the Maeslant Barrier, separates the North Sea and the Rhine. During the storm, the closed gate holds the flow of the river and the surge from the sea, protecting the city. However, the feeling of security could be illusory due to its probability of failure and lack of alternative or supportive solutions. The gate will not be effective in the future with current SLR predictions. It is not flexible and hard to adjust on a large scale. The gate will have to remain closed more often in the near future, which will stop the navigation to and from the port (van den Brink, de Goederen, 2017).

Figure 3.2. Maeslant Barrier

Maeslant Barrier is also an example of one of the criticized aspects of the Dutch model, prioritizing the safety of the people over the natural environment. Due to a high density, Dutch responses to SLR are aiming at providing "a safe and well inhabitable country" (M. Vankoningsveld et al, 2008) focusing on socio-economic systems rather than on socio-ecological ones.

While "working with nature" was addressed as one of the biggest challenges for the 21 century (M. Vankoningsveld et al, 2008.), the Delta Programme Report 2019 still treats ecological sustainability as a side goal without proposing any specific actions.

STATEN ISLAND

New York, USA

152 km² - third biggest NY borough

476 200 - population (5% of NYC, 2,5% of NY)

3 132/km² - density (lowest in NYC)

- land area of Staten Island
- land outside Staten Island
- river and bays

Figure 3.3. Map of Staten Island

Hurricane Sandy is an example of worsening trends of extreme SLR events. Hitting the northeast coast of the US in 2012, it destroyed human lives, damaged critical infrastructure, caused irreversible degradation of the natural environment and more than a $65 billion in damages and economic loss. The hurricane exposed how vulnerable the city of New York is to natural disasters (Finucane, 2014).

Rebuild by Design created by Shaun Donovan with Henk Ovink was the most innovative response to SLR so far. Based on the Dutch model, it provided a model of how the collaboration between public and private stakeholders creates innovative responses for vulnerable communities.

It started in 2013 as a multidisciplinary design competition launched by the US housing department. However, the goal was not to provide an answer to the challenge but instead to expose what the challenge is. Ten finalists teams carried on with a year-long process of research and investigation, collaboration with community stakeholders and analysis of local conditions and needs. Designing a holistic proposal was only the middle phase in choosing seven winning proposals that would later be implemented over a longer period of time (Ovink, Boeijenga, 2018).

The SCAPE / LANDSCAPE ARCHITECTURE team was working with communities on Staten Island.

Figure 3.4. Process of Rebuild by Design, adapted from Rebuild by Design, 2015

Staten Island was one of the most damaged places in New York during Hurricane Sandy. Its exposure is mostly a result of long-term degradation of natural and farmed oyster reefs in Raritan Bay, which used to play a major role in the ecosystem and economy of the community (Gendall et al, 2015).

The Living Breakwaters is an integrated design that connects risk reduction with strengthening social resilience and ecological restoration. It proposes a number of in-water protection layers with on-shore interventions. It consists of several solutions such as Living Breakwaters to provide protection and a new habitat for ecosystems, or Active Oyster Restoration that features installations in the breakwaters and involves off-site activities to cultivate the tradition. It is based on collective insight from the community, gathered through interactive workshops and meetings, walks and beach clean-ups (Gendall et al, 2015).

From the beginning, the goal of the project, both the research part and the design, was to identify opportunities instead of building a wall or stopping the SLR.

The project is planned in phases that include a pilot development on Tottenville shore, the most vulnerable one, and plans to extend the initiative over time.

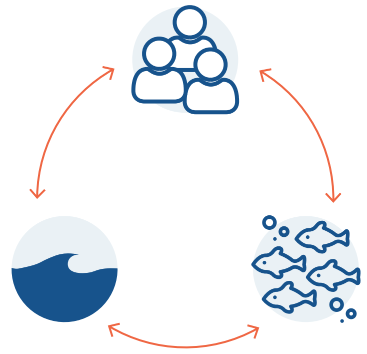


Figure 3.5. Purpose of Living Breakwaters, adapted from Rebuild by Design, 2015

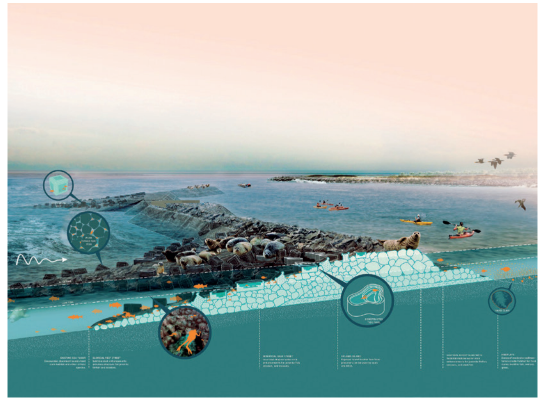


Figure 3.6. Living Breakwaters, Rebuild by Design, 2015

MAHÉ

Seychelles

157.3 km² - biggest island of Seychelles

85 300 - population (88% of country's population)

111.3 km - coastline

Victoria - capital

- land area of Mahé
- Indian Ocean

Figure 3.7. Map of Mahé

The Republic of Seychelles is a small archipelago country in the Indian Ocean with a population of almost 97 000 people (the smallest in Africa). The country used to be a British colony but gained its independence in 1976. Its biggest economic sectors are agriculture, services, the public sector and tourism (World Bank Group, 2017).

As a country that is spread out across 115 islands, mostly low-lying atolls, it is among the most vulnerable to rising sea level. The total of 491-km-long coastline means that most people are exposed to flooding and extreme storms (Magnan et al, 2019).

The economic growth of Seychelles is hugely dependent on the fishing industry and upmarket tourism focused on beach recreation activities (World Bank Group, 2017). Those sectors are closely related to the ocean environment, therefore will be impacted by climate change (Magnan et al, 2019). Disappearing beaches will reduce the number of tourists. Losses in biodiversity will cut down the fish stock.

Due to its close relation to the natural environment, in the last couple of years several environmental projects have been initiated. Seychelles Sustainable Tourism Foundation is working with hotels and tourism activities centers to reduce tourists' impact on the natural environment (Seychelles Sustainable Tourism Foundation, 2018).

The Blue Economy Knowledge Centre launched a coral reef restoration project. It collects small pieces of live coral, raises them in underwater coral nurseries and transplants them to degraded sites. More developed corals will spread out faster, creating coral gardens that not only provide rich marine habitat but also work as natural breakwaters and reduce erosion. The project also started a training program for international participants to share their experience with other countries dealing with coral bleaching (The Blue Economy Knowledge Center). Most recently Seychelles extended its marine protected area to 400,000 km² and reached the goal of safeguarding 30% of its marine waters (The Seychelles National Parks Authority).

The government of Seychelles has put a lot of pressure on the Blue Economy as the way to retain economic growth without sacrificing the natural environment (Blue Economy Department). Yet, due to other social challenges, the country is lacking research resources dedicated to SLR and ocean degradation, and so is fully dependent on foreign investments (World Bank Group, 2017). One of the biggest issues is low education enrolment. In 2018 only about 35% of secondary education students continued their studies at the tertiary level, with only 6% enrolling into university programes (National Bureau of Statistics, 2019). This dependency on expatriate knowledge is preventing site-specific solutions and increases vulnerability.

Mahé is the biggest island and home to 88% of the population (World Bank Group, 2017). It is the center of the country with the capital, Victoria, an international airport, the government, a university and one of the country's major employers, the Indian Ocean Tuna Limited. Seychelles' biggest export product is canned tuna (83% of country's whole export product) and most of it comes from the factory.

The island is constrained with spatial growth. Despite being the biggest island in the archipelago, it is struggling to accommodate the growing population and protect the ecosystems. High hills in the middle of the island reduce the development possibilities and the country decided to create a couple of artificial islands to provide the space for luxury housing and industrial estates, creating an even more vulnerable system.

Figure 3.8. Ile Perseverance, an artificial island

NOTE:
The main research about Seychelles was supposed to be conducted during a field study, through interviews with different stakeholder groups. The contact with a local source, who helped to organize the trip and set the interviews, was uneven, which caused a lot of confusion. The process of organizing the trip and setting the specific dates was very long and I was specifically asked not to contact other sources on my own.

After the COVID-19 outbreak (March, 2020), when it was clear that I could not pursue with the field-study trip, I was assured that I could get the information I needed to carry on with the thesis. However, the attempt to organize a short survey failed, caused by the fact that the survey was not passed on to the groups, or the lack of willingness to participate from the stakeholders themselves. Moreover, almost all of the emails that has been send from me directly to the possible collaborators, were left without any answers.

This lack of collaboration might indicate the non-transparent socio-political structure that reduces the organizational capacity and make interdisciplinary projects limited.

SUMMARY

All three case studies are vulnerable to the ocean changes and the related risks. The Netherlands are recognized as the best-prepared for SLR, however, the analysis shows that they are still coping with similar challenges.

In Rotterdam, the biggest issue is a threat to existing infrastructure if the Maeslant Barrier were to stop providing protection.. The Dutch model does not provide positive environmental impacts, which will have catastrophic outcomes for the natural ecosystems and, consequently, for the people.

Staten Island shares the threat to the existing infrastructure, which is complemented by danger to human activities along the coastline. However, their layered proposal is not dependent on one solution to protect the entire community.

Mahé is indisputably the most vulnerable one among the three cases, but their commitment to protecting the natural environment is profound. Despite differences in location, social context and economic status, all of the studied cases are coping with the same challenge to climate-proof their communities and to reduce global warming.

Climate change creates most of the risks in the first place, however responding to its threats needs to be combined with climate-proofing the country, as it is impossible to try to solve one part of the problem without the other. It is necessary to treat those two challenges as one, to reduce the vulnerabilities and strengthen coastal communities.

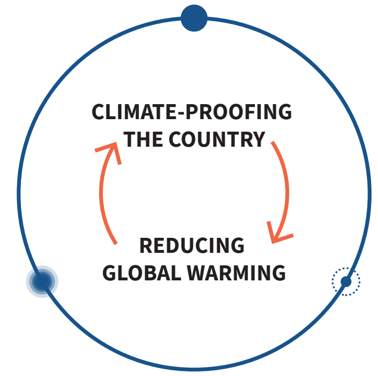


Figure 3.9. SLR challenges for coastal communities

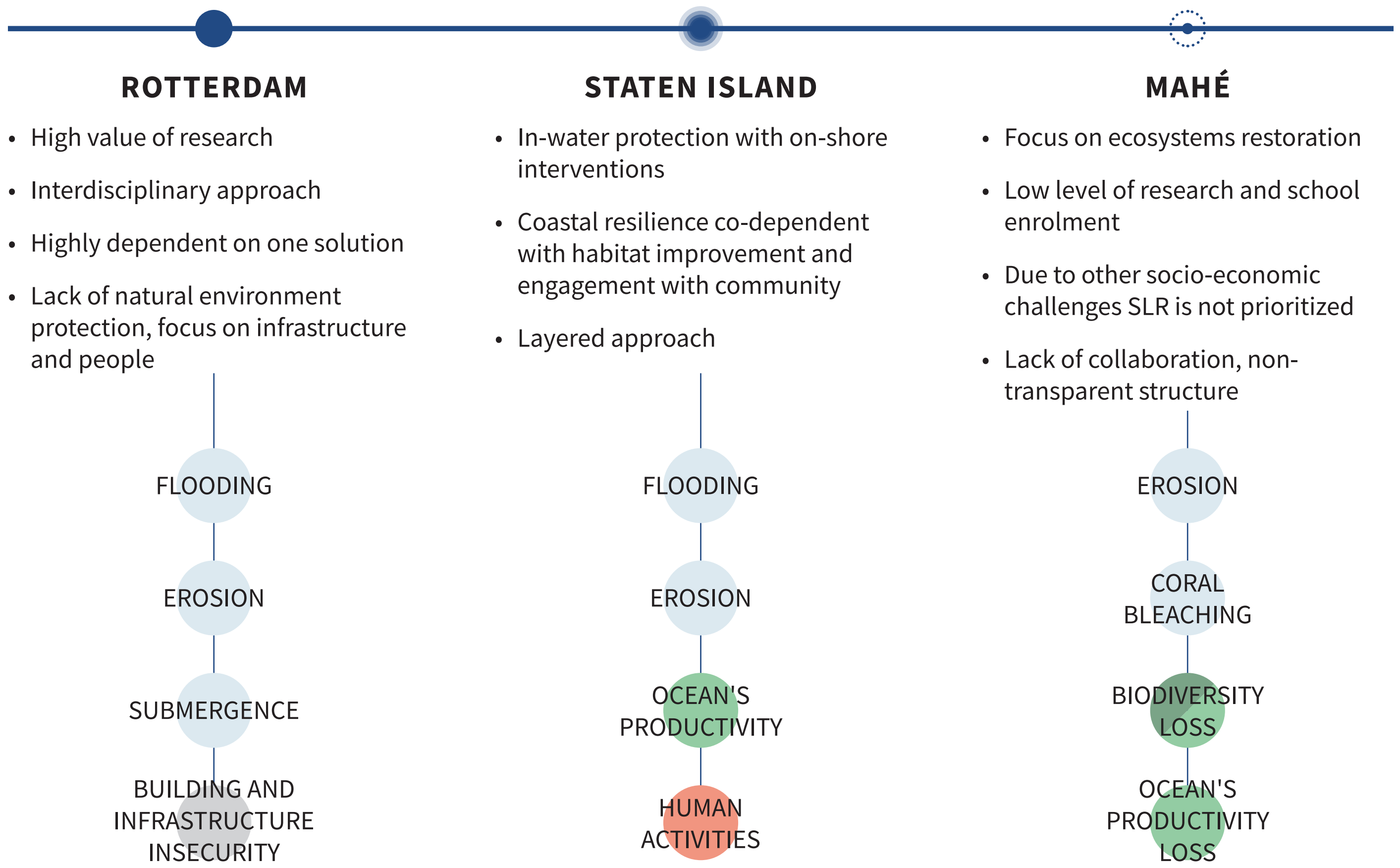
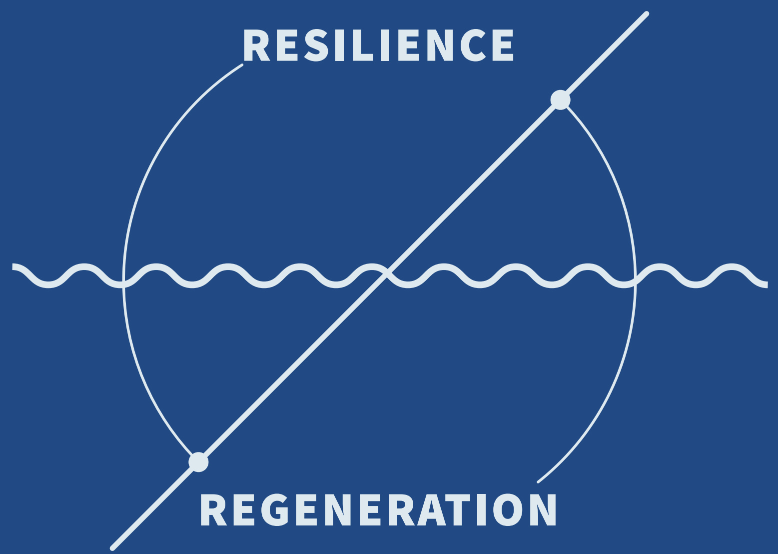


Figure 3.10. Biggest risks characterizing each location

04

THE THEORY OF RESILIENCE



RESILIENCE

The complex net of risks related to the ocean and urgent attempts to reduce climate change require comprehensive, long-term approaches. In time of great risk it is easy to rely on hard protection, like dykes and breakwaters, especially since historically they were the most popular ones. As an existing but long-time insufficient model they provide "the false sense of safety by keeping the water away" (Ovink, H., Boeijenga, J., 2018).

Due to uncertain predictions, not all incidents can be prevented. The acceleration and unpredictability of the sea level changes makes adaptable constructions alone inadequate(Oppenheimer et al, 2019). Neither mitigation nor protection alone can reduce the vulnerabilities of the coastal environments, which brings us to the discussion about resilient approaches to prepare for the unknown.

The concept of resilience, has been adopted in many disciplines, including architecture. The capacity of the system to withstand disturbance in a moment of shock is widely known in fields of social resilience, engineering resilience and ecological resilience (Comfort, Boin, Demchak, 2010).

In the context of this thesis, resilience stands for the ability to absorb adversity, adapt and recover from extreme sea events.

Resilient design responds to the local vulnerabilities by providing basic human needs, shelter, fresh water and food during the disturbance . It also makes it possible to rearrange and recover afterwards (Resilient Design Institute, 2013).

Extreme events are hard to foresee and prevent every time. The ability to absorb the obstacles and grow, dominates the efficiency. Therefore, resilience brings more flexibility compared to adaptation or hard protection (Comfort, Boin, Demchak, 2010).

It also means that the recovery process is completed within the system. The resilient building, therefore, should be adaptable to the changing environment and flexible for future changes, both short- and long-term ones. Self-organization allows the stakeholders to improve or repair it within their own capability. During uncertain times the systems that are able to prepare for the unknown are the strongest (Biggs, Schlüter, Schoon, 2015).

This strength comes from the complex interconnections and dependencies between components. When one or more connections are damaged, the system is able to reorganize and sustain its functions and slowly adjust. Diversity within the system helps with the reorganization ability and the response to interruptions (Biggs, Schlüter, Schoon, 2015).

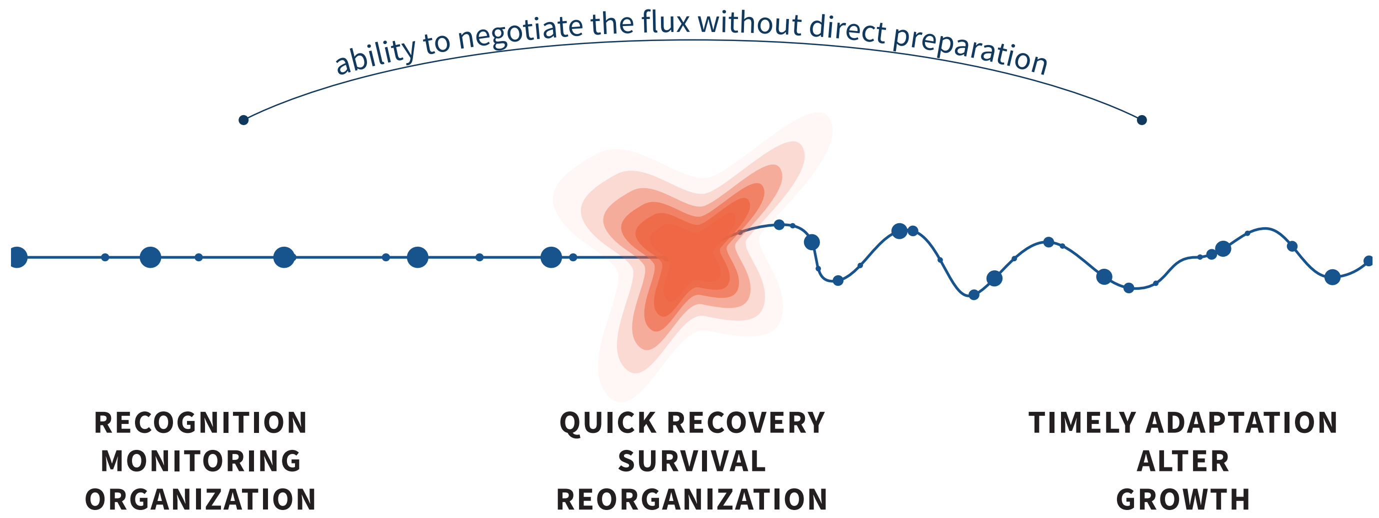


Figure 4.1. The theory of resilience

Unpredictability and uncertainty of the future predictions calls for a vernacular approach, as architecture is inseparable from the environmental context and constantly influenced by any changes (Mileto, Vegas, García, Cristini, 2015). The duality of resilient architecture means that at the same time it forms the space around and is being shaped by the surrounding environment.

With more people moving closer to the ocean it is impossible to ban coastal living. It is, however, fundamental to make informed decisions and to plan for the dynamic future.

In order to prepare for the uncertain future it is recommended to follow the adaptive decision making process (fig. 4.2). The process starts with setting the stage for identifying the risks, objectives and possibilities and setting the criteria for evaluating options. The analysis is followed by the development of a dynamic plan that combines options over time and includes corrective actions for the future. The next step is the implementation of the initial plan on the site and the start of the monitoring system to track the progress and recognize new potential threats. The last step of the process is continued monitoring of the changes and taking corrective actions as called for in the observed situation, and lastly to reset the stage if the actions are deficient (Oppenheimer et al, 2019).

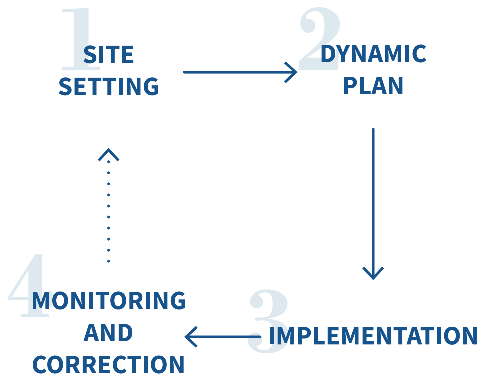


Figure 4.2. Adaptive decision making, adapted from IPCC, SROCC, 2019.

REGENERATIVE DESIGN

To achieve social and ecological resilience it is crucial to conceive of the natural environment and humans as one system rather than two supporting organizations.

Sustainable design brings back the balance between humans and nature with equity of actions and services between those two systems. It slows down the degradation of ecosystems, however, it does not repair the huge irreparable damage, that we have already caused to the planet (Mang, Haggard, 2016). To minimize climate change, we have to reverse the direction of changes.

Regenerative design pushes the idea of preventing the ongoing changes even further, by putting humans as one of the active participants in the whole structure. Humans are not "doing things to nature" but are participating in the co-evolution process of the entire system (Lyle, 1994).

Regenerative design is based on the integration of social and ecological subsystems. The structure eliminates the distinction between winners and losers in the exchange of actions and services.

One inclusive system encourages more positive actions that are beneficial for all. The cohesion allows for wider perspectives of growth instead of seeing actions and services as a trade that could be profitable for one side only. Moreover, the indirect exchanges can bring more value that is hard to measure using the typical concept of trade (Hes, du Plessis, 2015).

Regenerative development provides the framework to ensure that the design processes can exist. The development consists of three phases. First, it focuses on the recognition of the environment and existing patterns: the complexity of ecosystems and social systems and site specificity. Second, it supports the natural processes, for example by repairing existing damages. Third, it involves the direct and indirect exchange between actors that enlarges the potential of the entire system (Mang, Haggard, 2016).

The regenerative approach focuses on processes rather than building a product or capital. The goal of regenerative design is to support the positive co-evolution by building "capability", not infrastructure itself (Mang, Haggard, 2016).

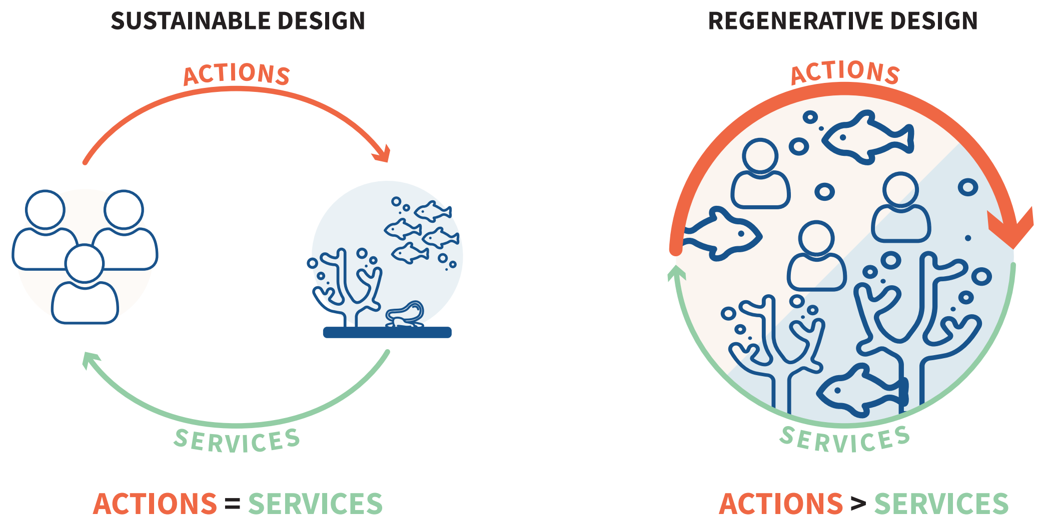


Figure 4.3. Sustainable design and regenerative design

The existence and health of the regenerative processes increases the ability and creativity to work with distractions. Not only does regenerative design make a positive impact on the system but it also reduces the vulnerability to external interruption (Hes, du Plessis, 2015).

Natural marine structures provide many examples of small regeneration processes, such as sponges. Their ability to recover from damages is extraordinary. Even small cells can migrate, settle and reconstruct (Biomimicry Institute). Biomimicry means looking at nature as an example of the working processes that have been evolving over thousands of years to follow the fast-changing environment. Imitating the natural processes, rather than copying their visible forms, can provide an inspiration for self-healing and self-organized capacities of living systems.

Regenerative design is inclusive and based on polyculture rather than favoring one kind or group over the others. The diversity of actors ensures complex interactions that contribute to the health and stability of the system.

SUMMARY

Similarly to the challenges of climate-proofing and reducing climate change, resilience and regeneration are inseparable. Both of them are based on similar patterns, however, they target different sensitivities.

Both are based on complexity and connectivity, rather than linear or central organization. Both support inclusiveness and diversity, rather than monoculture, to improve the capacity of their processes.

Climate change is unstoppable, but instead of falling into despair of the hopeless future, we need to reduce the trauma. Change can be good, however, we need to be proactive about it so it will not bring more degradation and suffering (Hes, du Plessis, 2015). Through collective efforts of strengthening resilience and applying regenerative solutions we could significantly reduce the vulnerabilities of coastal communities.

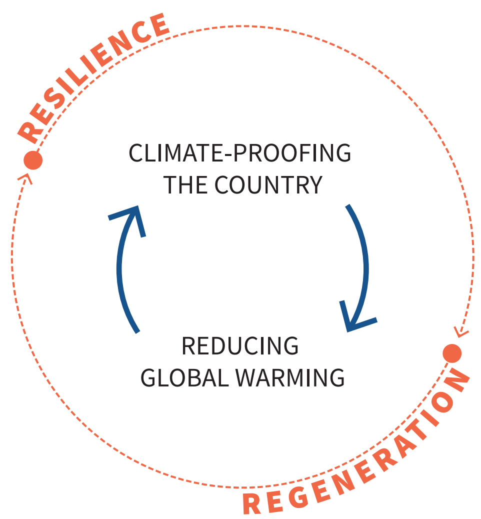


Figure 4.4. Resilience and regeneration

05

THE MANUAL

MANUAL FOR RESILIENCE AND REGENERATION

Large-scale diagnosis of risks related to the ocean change and analysis of the case studies has been filtered through the concept of resilience and regenerative design to create nine design strategies for resilient and regenerative architecture for coastal communities.

The strategies are a response to risks presented in figure 2.5 and the biggest vulnerabilities of coastal defenses programs in Rotterdam, Staten Island and Mahé. The strategies have been created in the framework of resilience and regenerative design to reduce the exposure of coastal communities.

The guidelines relate to the process of planning, the structure of the building and its function, necessary to decrease vulnerability of the community and maintain the health of the socio-ecological systems.

Those guidelines are for all coastal communities struggling with ocean changes. Each one of the rules can be applied in the design process and is adaptable to the scale, density, and budget. Implementing those strategies into the specific site requires analysis of the local context in terms of social structures, ecosystem and local building techniques and typologies.

DESIGN STRATEGIES

COMPOUND

Compound design is composed of separate units or actors. Contrary to one big-block solution, it should be a combination of components based strongly on interconnections and dependencies between them.

In the moment of shock or failure of one of the parts it will be easier to recognize and repair the damage and keep the rest of processes undisturbed and maintain the functions. The separation between parts supports quicker repair or replacement. The connectivity allows for quicker changes and faster recovery without stopping the basic functions of the entire system (Biggs, Schlüter, Schoon, 2015).

Therefore, smaller separate buildings or constructions with different functions, which are closely connected, are more resilient than one multifunctional block.

Compound design creates more possibilities to arrange different functions and, therefore, response to the building and infrastructure insecurity, when many processes are being stopped by damage to one part of the building.

Connectivity also involves a number of stakeholders and the relationship between them. A high quantity and quality of social interactions leads to knowledge exchange and strengthens trust and reciprocity (Ovink, Boeijenga, 2018).

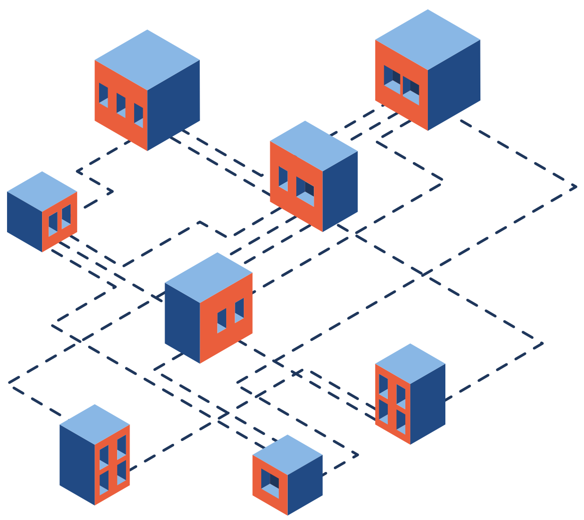


Figure 5.1. Compound structure

COMPREHENSIVE

In a fast-changing environment and with unknown future repercussions, responding to the coastal hazards by choosing one kind of construction is not effective. Hard protection like dykes or dry-proofing the buildings might not be enough if the sea level will increase above current predictions and extreme events will intensify (Kwadijk et al, 2010). Therefore, the new infrastructure must be working with different kinds of responses to strengthen the infrastructure.

Any vulnerable coastal community should not rely only on adaptation (Oppenheimer et al, 2019). Whenever it is wet-proofing or dry-proofing buildings, creating more efficient drainage systems or developing amphibious architecture, it is necessary to complete it with sustainable protection and in the most sensitive places to create a retreat plan. No matter how unthinkable the idea of the retreat is, well-organized evacuation will always be less traumatic than urgent displacement.

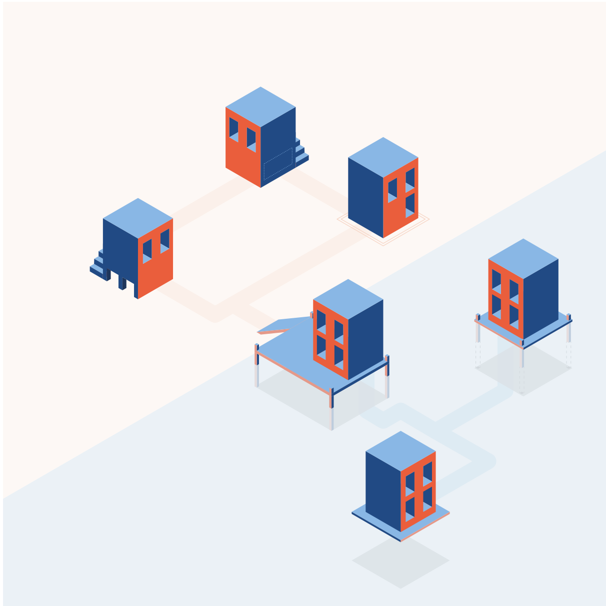


Figure 5.2. Comprehensive approach

MULTI-LAYERED

The multi-layered strategy comprises different layers of protection, both vertical and horizontal, to create different kinds of defense. Building a single wall or a gate has a high potential of failure that could lead to catastrophic damages.

Learned from the case study of Rotterdam, relying on one kind of protection, no matter how advanced, in long term perspective is inefficient.

Relying on different lines of protection is not only comprehensive and more flexible in protecting against different risks but also eliminates a situation in which a community becomes unprotected due to the failure of one component.

Starting from the monitoring of changes and responding to them, all layers should be adapted the local abilities and context. They should include cross-sectional solutions both in water and on-shore. The combination of subtidal reefs, coral gardens and wetlands should be implemented with adaptive architecture, a drainage system and stormwater storage.

Complex protection using ecosystem-based adaptation will at the same time increase biodiversity and result in strong ecological resilience (Mant et al, 2016).

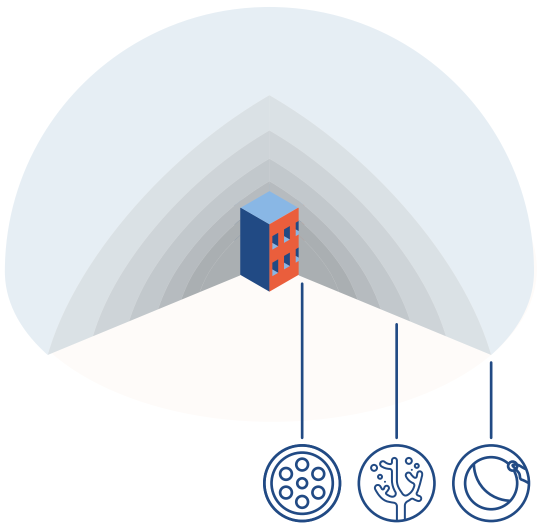


Figure 5.3. Multi-layered protection

FLEXIBLE

Easy to adjust or change over time. Following the concept of adaptive decision making, the building construction needs to be flexible to accommodate continuous alteration and growth.

Easy, preferably grid construction needs to grow with subsequent phases of development and the growing demands (Pfammatter, 2014). The scale of the structure has to be easy to expand when more space is needed.

The building also needs to adjust to both the dynamic environment and the new changing technologies, whether they are going to be bigger or smaller, following the nano trends.

The building has to follow the advancement of the place and progress in local skills and technical abilities (Museum of Modern Art). This strategy is especially important in developing countries in order to retain self-organizational aspect of the building at the beginning but not to create an obstacle for future development (Pfammatter, 2014).

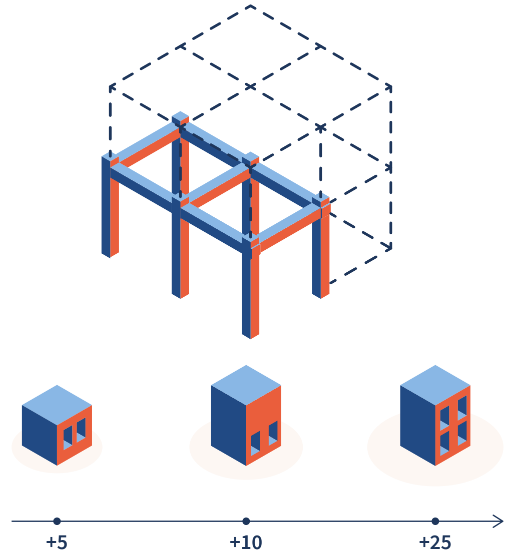


Figure 5.4. Flexible construction

ADAPTABLE

In view of the constantly changing environment and SLR, adaptability seems like an obvious principle.

However, adaptable architecture, in this case, means the capability to exchange functions without extensive resources. Changing demands and circumstances require an easy layout to provide more possible arrangements (Pfammatter, 2014). The clear structure of the space provides more options to introduce different functions rather than a couple of irregularly shaped rooms connected with complicated corridors.

With building and infrastructure insecurity the requirement for the existing or new infrastructure rise and it is important that architecture meets those demands. For example, the same space might be used to organize a classroom for the kids during the day and to provide a space for community meetings in the evenings.

Adaptable solutions, also, encourage adaptive decision making process of the development.

The proportion between the needs might change over time. With the growing awareness of the community, a construction that started as an educational space, after a couple of years might change into a training center for a retreat and provide a space to organize workshops about sustainable aquaculture.

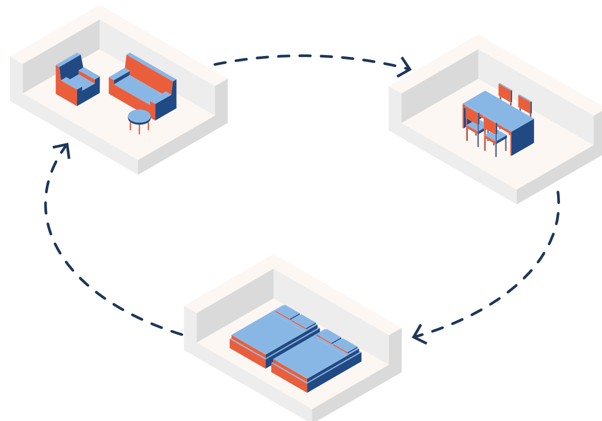


Figure 5.5. Adaptable layout

RAISING AWARENESS

Coastal communities have a close relationship with the ocean but some have no detailed knowledge of why and how this connection works. A deeper understanding of the socio-ecological systems is always incomplete due to its continuous development (Schwerdtner et al, 2014).

To build up the resilience of the community, architecture should encourage continuous learning and experimentation (Biggs, Schlüter, Schoon, 2015). It should raise awareness about the marine environmental changes, how to co-evolve with the ocean, and how to protect ecosystems, and how it could protect us at the same time.

That focus on learning could mean expanding the knowledge by providing research facilities and a space for science and experiments. But it should also spread information among the wider public, by providing exhibition spaces or lecture rooms.

Moreover, the architecture itself needs to provide an example of how and where to build in the coastal environment to support the system, and what to do in case of emergency.

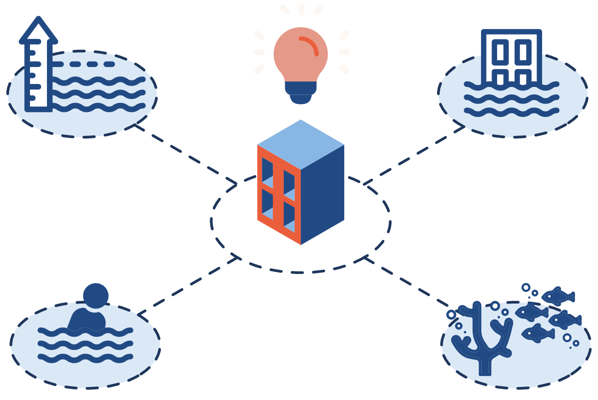


Figure 5.6. Raising awareness function

SELF-ORGANIZED

Self-organized is one of the characteristics of complex adaptive systems that allow them to grow, order, and organize all by themselves, without outside supervision (Biggs, Schlüter, Schoon, 2015). The systems use self-sustaining adaptability to change within their own environment, with their own skills.

Self-organized architecture in the context of resilience means that the community is capable of restoring the building or adjusting it without outside contractors. This self-sufficiency tightens the relations inside the community and accelerates the speed of reacting to unexpected events.

Self-organization endorses the use of local materials and working with more easily available solutions, rather than reaching out toward more complicated structures.

Using local techniques and materials shorten the time of recovery after the extreme event and reduces building and infrastructure insecurity by strengthening the capabilities of the local community to recover within their system. A wide knowledge of the context, both natural, social and economic, is crucial for this strategy.

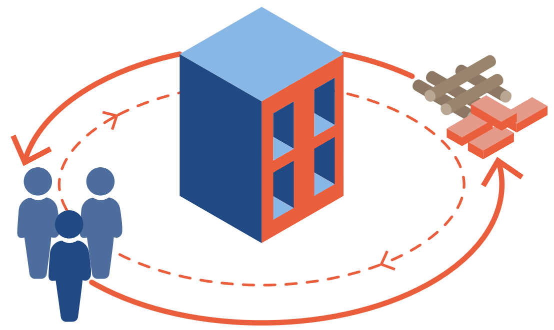


Figure 5.7. Self-organized design

HOLISTIC

Three areas of risks related to ocean changes: ecological, social, and economic, correspond to three dimensions of resilience: ecological, social and engineering (Comfort, Boin, Demchak, 2010).

Strengthening the resilience of the coastal system requires working with all of them rather prioritizing one over the other. The closed loop of services and actions loses its stability if only one of the subgroups is benefiting from the exchange.

Therefore, the design should enhance and restore the ecological processes and build up existing ecosystems. It should protect the social structures and provide a safe environment for people to carry on with their activities. Additionally, it needs to provide opportunities for economic growth and sustain existing businesses and structures.

Bearing in mind the necessity of balancing between social and ecological subsystems, which has been mentioned before regarding regenerative design (Fig. 4.3.), it is important to remember about the significance of economic actors. Restoration of the natural ecosystems cannot prevent economic development as it widens the gap between developed, developing and least-developed countries and increases inequity (Patil, Virdin, Diez, Roberts, Singh, 2016)

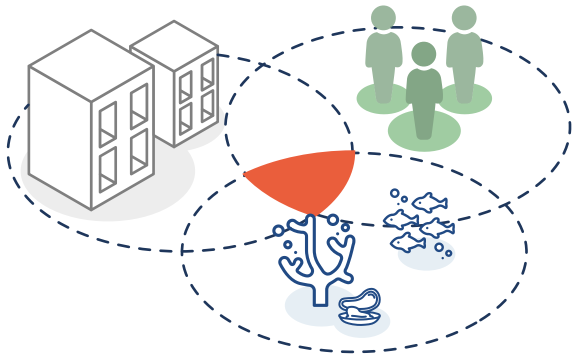


Figure 5.8. Holistic means

POLYCULTURAL

One of the biggest strengths of natural ecosystems is their diversity, which causes interdependencies and connectivity. To build up the resilience of the system and create new services and benefits it is crucial to support polycultural environment and to enhance differences (Biggs, Schlüter, Schoon, 2015).

Regenerative design creates an environment for all species to thrive: fish, kelp, shellfish, plankton and others. It increases biodiversity, by providing the net of interactions between different species.

Coastal communities are strongly dependent on the ocean as a source of food. Relying on one kind or group of species in terms of aquaculture increases the vulnerability to food insecurity (Magnan et al, 2019). For example, when one kind of fish, which is the basis of a given community's diet, becomes extinct, it creates a bigger disruption to the community than if it were just a part of their daily food. Polycultural design can reduce the risk of food insecurity by providing alternatives in aquaculture and reducing the dependency of one species.

Figure 5.9. Polycultural focus

DIFFERENT CONTEXTS

The nine strategies are related to new coastal development and the restoration of existing infrastructure. They are used to improve the design that strengthens coastal communities, by reducing the exposure and raising preparedness. Simultaneously, the strategies are encouraging close connections with the ocean, both literally and metaphorically, and they support the exchange of services and actions between all actors of the socio-ecological system.

The guidelines are not site-specific and are recommended for all locations struggling with ocean change. Depending on the specific risks, location, the scale of the issue and further implications, economic status and other societal challenges, the proportion between them should shift. All of the strategies are important and need to be applied; however, they are not equal.

For example, Rotterdam's biggest vulnerability is dependency on the Maeslant Barrier and low consideration of natural ecosystems. The biggest pressure should be put on creating a multi-layered protection system and shifting to a holistic perspective, rather than focusing only on protecting the people.

Damages after Hurricane Sandy on Staten Island were so horrifying and overwhelming that an immediate return to the pre-Sandy shape was impossible. To sustain the existing environment and recover over time, the focus should be put on compound planning and adaptable solutions that could provide space for different functions at the same time.

Mahé's biggest risks are coral bleaching and ocean productivity loss. It also struggles with a lack of research resources and dependency on expatriate knowledge. Development should be focusing on including polycultural solutions and raising awareness among the communities. Its unique remote location requires the design to be self-organized, in order to reduce the dependency on imported goods and skills.

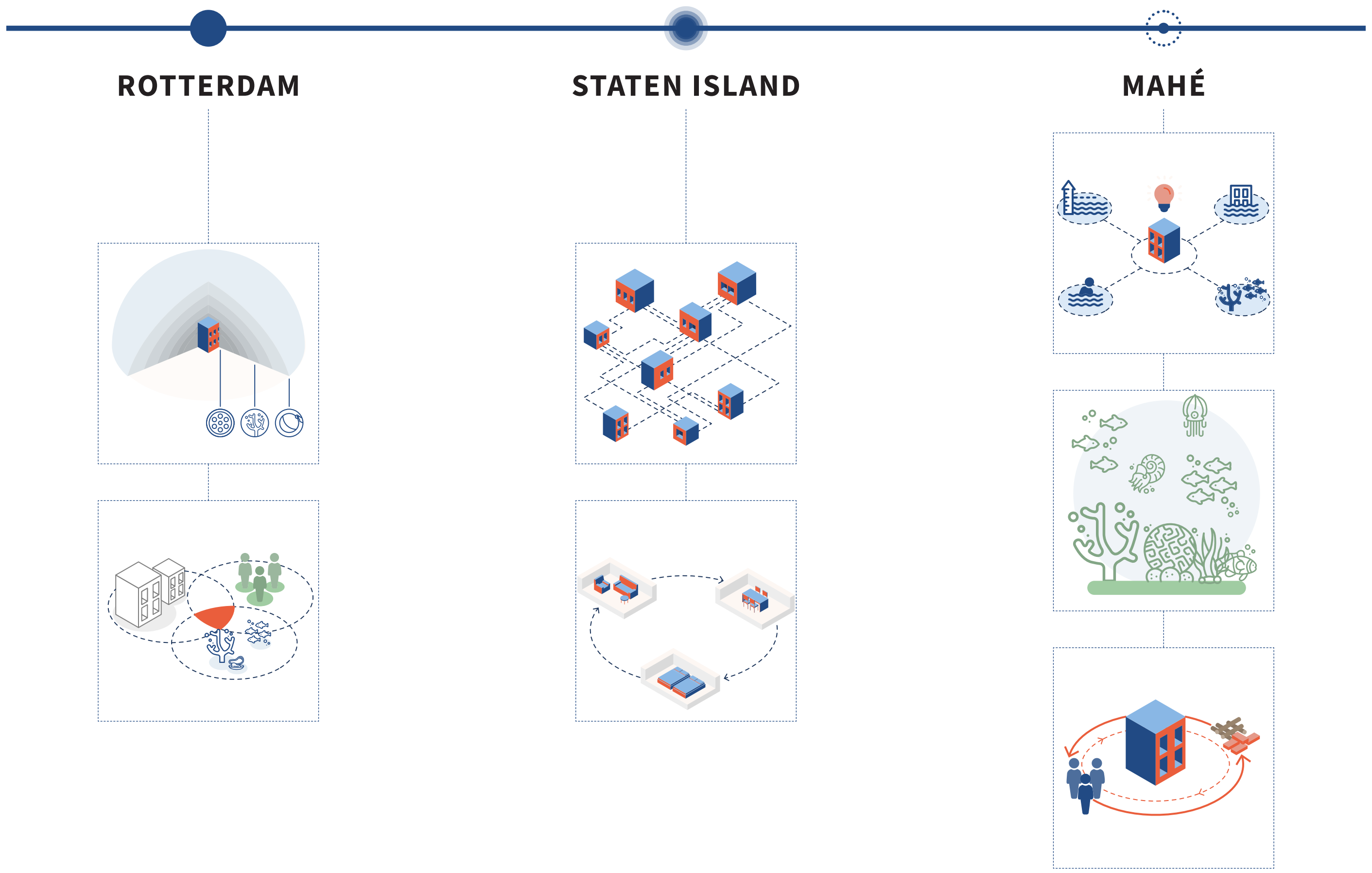


Figure 5.10. The most important design strategies characterizing each location

STRATEGIES FOR RESILIENT AND REGENERATIVE ARCHITECTURE OF COASTAL COMMUNITIES

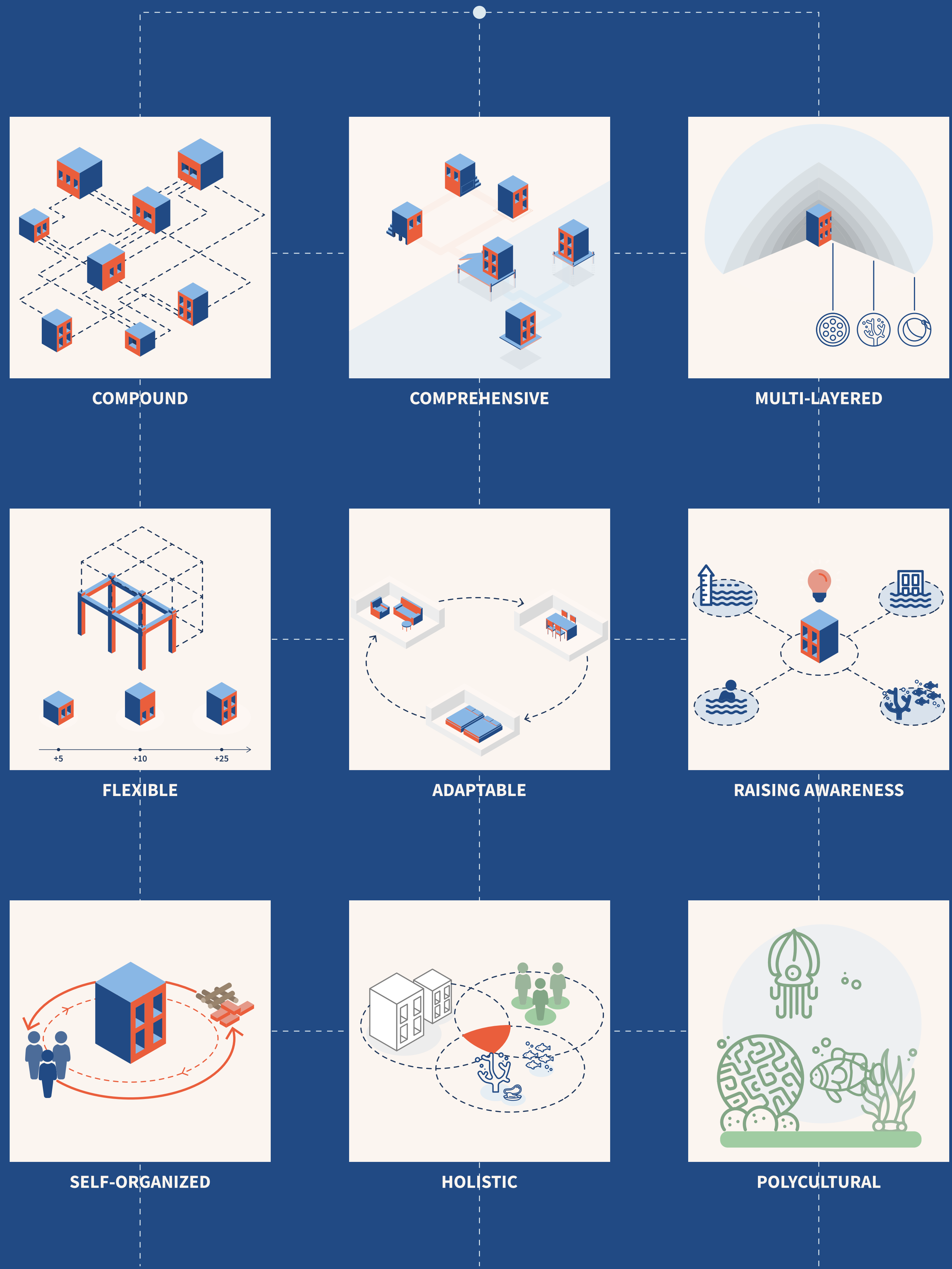


Figure 5.11. Summary of design strategies

06

DESIGN STRATEGIES IMPLEMENTATION

COMMUNITY PARTICIPATION

Because of the important role of the local communities in the process of risk reduction it is important to conduct a complex, on-site analysis of the local context (Davis, Krimgold, Thompson, 2015).

In normal circumstances, the next phase of the thesis would include a field-study trip, during which a big part of the research was supposed to be carried out. The analysis was to include interviews with different stakeholder groups and policy-makers, site visits and the analysis of local typologies and technologies. However, because of the pandemic of COVID-19 the field-study trip had to be cancelled, making the research about the local context limited.

This chapter offers recommendations for what should be the next phase of the thesis. It focuses on how to implement the design strategies, which are general and globally adaptable, in the specific context of a local coastal community. It emphasizes the importance of understanding the local environment, culture, processes and interdependencies, as well as including local insight in the process of planning.

It is important to understand that under regular circumstances this is the right way to proceed with research about building resilient communities.

Post-disaster plans made by policy-makers and experts in the field of risk reduction often follow a top-down approach and rarely include insight from affected communities. This lack of inclusiveness results in generalization and standardization, which often leads to inappropriate or ineffective recovery interventions (UN Development Programme, 2020).

Developing a successful Disaster Risk Reduction (DRR) plan to build up coastal resilience requires deep understanding of how the local society works. Before designing the framework for a pre- or post-disaster plan or mitigation projects it is necessary to identify potential risks, local vulnerabilities, social capacity of the local community and local resources (ASF-Int., 2012).

This people-centered recovery approach connects the professional knowledge with needs and priorities of the exposed community. It strengthens their self-organizational

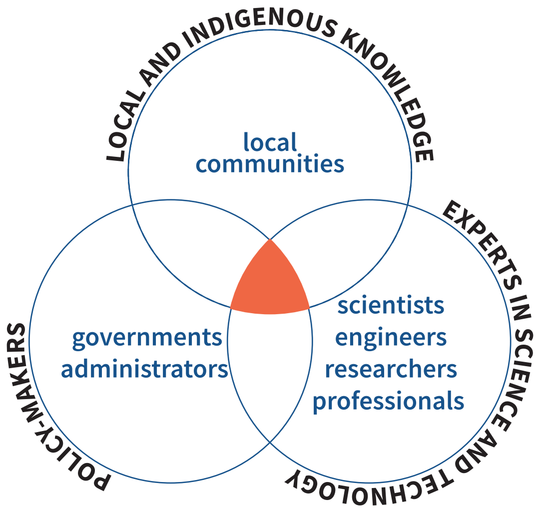


Figure 6.1. Risk management knowledge sharing

abilities by building up their awareness, skills and capacities. Community participation empowers local social structures and reduces their vulnerabilities to extreme events (UN Development Programme, 2020).

Participation mobilizes communities to develop a proactive approach and define measures for recovery before a disaster happens (ASF-Int., 2012). Community participation increases preparedness.

Figure 6.2. Framework for a DRR plan

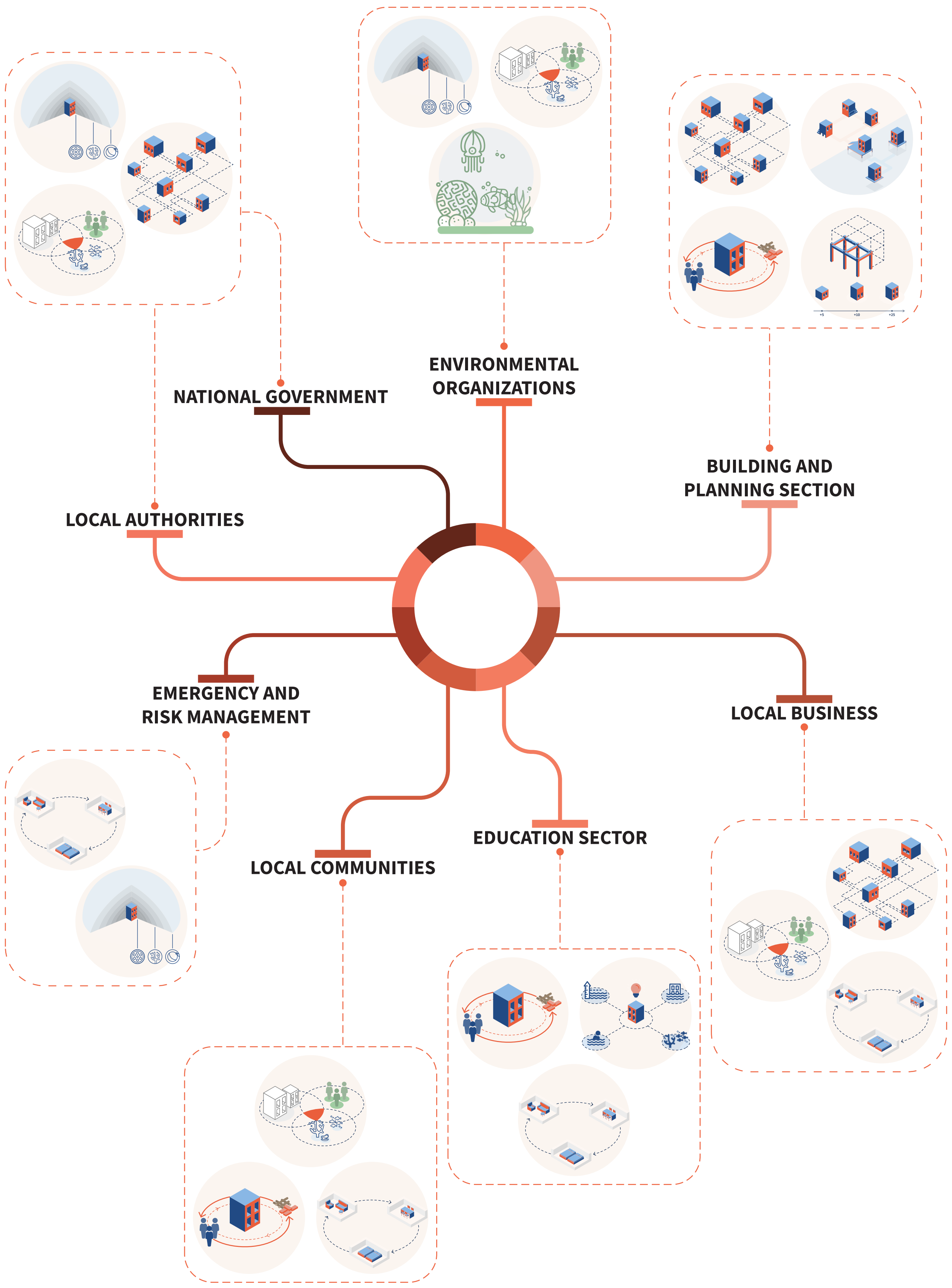


Figure 6.3. Stakeholders diagram

APPLYING DESIGN STRATEGIES

Applying design strategies requires collaboration with different stakeholder groups as they are the primary source of information about the local context.

Resilience is based on complex interconnections and dependencies; therefore, it is fundamental to include different stakeholder groups in the rocess of planning. Broad participation allows different perspectives to contribute to addressing threats and discovering new possibilities. It also helps to build up trust and exchange of knowledge (Biggs, Schlüter, Schoon, 2015).

It starts with **authorities**, both **national,** regional and **local**, usually responsible for the istribution of aid and managing the budgets. Smart planning is achieved by seeing the bigger picture, rather than just a single section, and it requires top-down management.

Risk management organizations are essential in ensuring a quick reaction in the moment of shock, therefore including them in the process of planning will encourage faster recovery.

Local businesses may vary in scale depending on the place. It could mean the Tourist Foundation and fishing organizations in Seychelles or it could be the Port of Rotterdam. Regardless of the scale, the support of the economy needs to remain active even during extreme events. “Resilient businesses make strong communities” (H. Ovink, J. Boeijenga, 2018).

Environmental organizations are an obvious contributor as they are the voice of the ecosystems and the natural environment.

Local communities support social activities and cultural patterns and, therefore, are fundamental in retaining public interactions and building up social resilience.

The education sector and facilities, such as schools and research laboratories, are imperative for processing the monitoring data and expanding the knowledge about environmental changes. They are also the biggest source of information for raising awareness about ongoing changes and the possible outcomes for the community.

The building and planning section delivers necessary information about the local building environment. Traditional building techniques, construction systems and material resources shape resilient architecture. Local insight into building environment creates a proposal more suitable for certain circumstances and local character.

ANALYSIS OF THE LOCAL CONTEXT

As mentioned earlier, Mahé is the most vulnerable to SLR and ocean degradation among the three case studies, therefore the field-study trip and the local analysis was planned for Seychelles.

Figure 6.4 shows the subsequent steps of local context analysis. The second step of the process, after choosing a specific site, is identification of stakeholders. Those stakeholders are later interviewed to make the next steps of the analysis, which emphasizes the importance of including stakeholders from the early stages.

Some guiding questions are presented in the diagram as an example; however, they may vary depending on the specific location or kinds of risks.

Organizations and groups presented in figure 6.4 are from Mahé, as the main method of on-site research was a set of interviews. Because the field-study trip did not take place, specific organizations here constitute examples of what parts could be included in stakeholder groups from figure 6.3.

The aim of the analysis is to determine the local design opportunities within the framework of resilient and regenerative architecture.

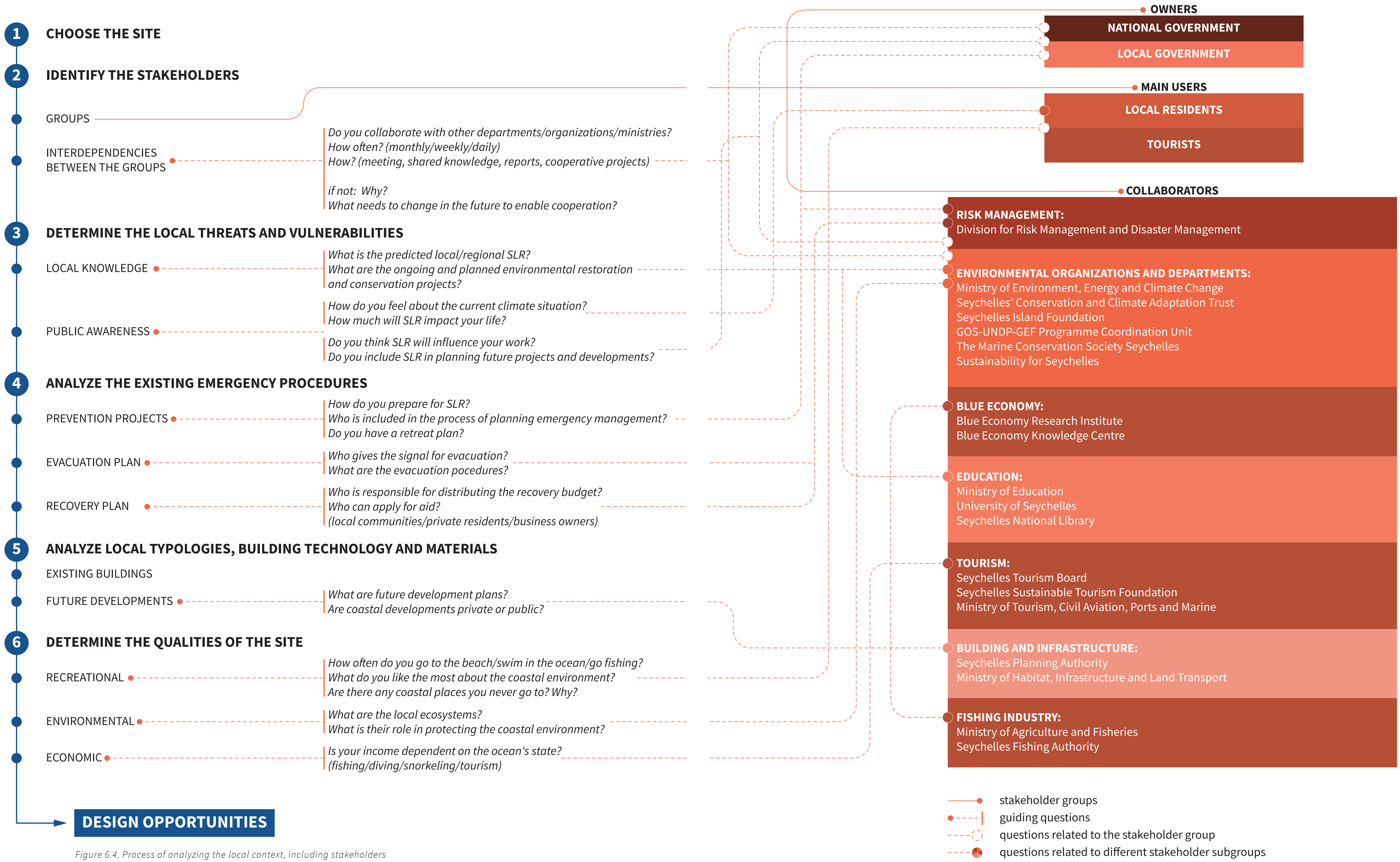
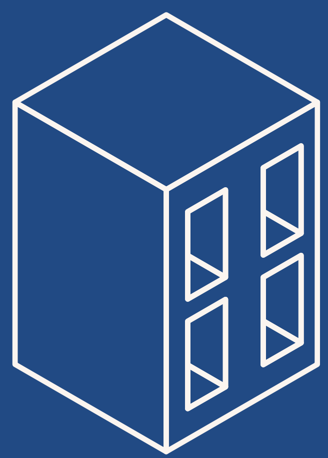


Figure 6.4. Process of analyzing the local context, including stakeholders

07

PROPOSAL



DESIGNING A SYSTEM

The design proposal plays the role of an illustration of the design strategies rather than site-specific building solutions. Therefore, the drawings are more of a manual featuring diagrammatic explanations of the processes within the proposal instead of standard plans and sections.

At the core of resilience are the processes taking place between components and the connections and interdependencies between them, and so the design is an explanation of how different parts influence the coastal community rather than a "ready to build" project.

Therefore, the proposal does not focus on technical solutions and detailed structures. Also, it does not contain contextual analysis. The lack of a site-specific approach makes it easier to adapt in other places that are dealing with similar environmental, social and economic challenges.

The design itself is a "water to shore" complex design in which separate buildings work as different components in the coastal system. The main concept is to provide a long-term structure that would reduce vulnerabilities of coastal community by constantly adapting to changing environment; using different protective solutions and reducing the climate change. In each part of the design there are implemented some design strategies. For better understanding , all of the drawing have small diagrams indicating which strategies are especially important.

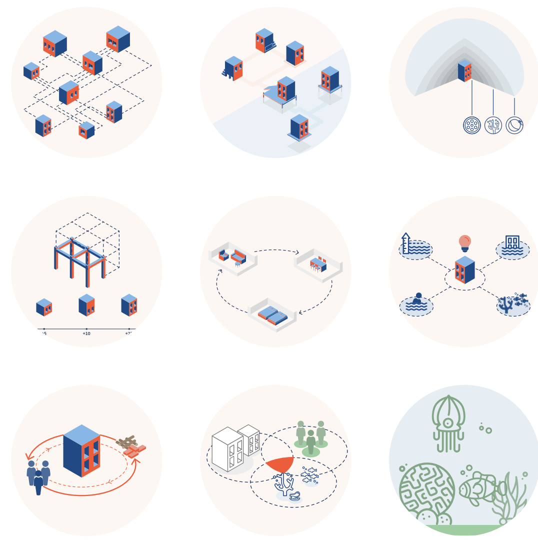


Figure 7.1. Indicators of design strategies

REFERENCE PROJECTS

ECOSYSTEM-BASED ADAPTATION (EbA)

It is a combination of protection and sustainable management, conservation and restoration of coastal ecosystems, such as coral reefs, wetlands and mangroves. The response is based on providing retention space, raising elevation and reducing erosion by stabilizing the sediments. It also works as an obstacle in case of storm surges and breaks the waves (Oppenheimer et al, 2019).

Many countries that depend on natural ecosystems for protection combine different restoration programs to protect the existing areas and reclaim the natural habitat. The process of re-plantation of mangrove forests or coral gardens support local economies by creating jobs opportunities (Mant et al, 2016).

Figure 7.2. Mangroves

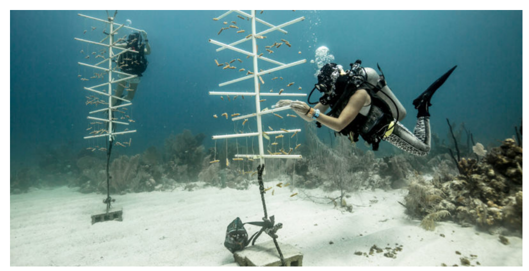


Figure 7.3. Coral nursery

3D OCEAN FARMING

A way a vertical farming in the ocean, which combines restoration of ocean ecosystems and commercial farming, to grow seaweed and shellfish for food, fertilizer and bioplastic. The structure is based on floating buoys on the surface and scallops, mussels and oysters in socks with kelp forests hanging from the lines. The farm is fixed to the ground by hurricane-proof anchors. Polyculture farming reduces food insecurity and unemployment when the fish stocks are decreasing. The concept has a small footprint compared to regular ocean farms and low economic barriers to entry , thus enhancing the economic revival in places affected by ocean change (Green Wave).

Figure 7.4. 3D ocean farming

Figure 7.5. Living seawall

LIVING SEAWALL

Collaboration between Volvo, the Sydney Institute of Marine Science and the Reef Design Lab in Sydney Harbour. The project mimics the root structure of the mangrove trees and its coarse surface attracts filter-feeding organisms. The goal of the project was to increase biodiversity in the harbour by adding modules. The project was based on existing infrastructure as a long-term response to the decreasing quality of water in the harbour (Volvo Cars).

Figure 7.6. Living seawall from Sydney Harbour

DR. O.H. PILKEY RESEARCH LABORATORY

New building for Duke University Marine Laboratory provided a programmatic example of a research facility with conference rooms, offices and laboratory with all of the supporting functions. Moreover, it created several "collisional" common areas throughout the entire building to encourage the informal meetings and knowledge exchange (GLUCK+).

Situated on Pivers Island, the building is shaped to withstand hurricane-force winds with impact-resistant glazing systems as well as ladding and roofing resistant to wind suction and windborne debris. The laboratory with its the expensive equipment has been put on the second floor to protect it from the risk of flooding. The landscape of permeable paver and drought-tolerant "sand dunes" absorbs the extensive water and minimizes the runoff. Design include reduction of heat island effect and uses geothermal ground-source heat for energy efficiency reasons (GLUCK+).

Figure 7.7. Dr. O.H. Pilkey Research laboratory

Figure 7.8. Common spaces of the laboratory

METI HANDMADE SCHOOL

A project of a school in Rudrapur, Bangladesh by Anna Heringer and Eike Roswag in 2004-06. It is a model awarded for the involvement of the village community and efficient construction methods using local materials. The ground level of the building is made in conventional heavy construction and contains three classrooms. The first floor is a light bamboo structure that creates an airy, multifunctional space for more informal gatherings and plays (Museum of Modern Art).

The project enhances pro-active development by using conventional construction methods and locally available materials to create a new typology. Using well-known materials and involving the community in the building process creates a self-orginized environment, and the building is easy to rebuild or repair without outside contractors. Additionally, the people involved in building the school learned new skills and construction techniques to later be hired to construct municipal projects. By combining two technologies, the building can be easily adapted for high-tech future changes, and therefore it follows the country's development (Pfammatter 2014).

Figure 7.9. METI Handmade School

Figure 7.10. Building process of the METI school

Figure 7.11. Omega Center for Sustainable Living

OMEGA CENTER FOR SUSTAINABLE LIVING

A project that connects regeneration, a new sustainable wastewater filtration facility, and education, classrooms, a laboratory and treatment cells, by BNIM (Berkebile, McDowell, Lesniewski, 2010).

The building in Rhinnebeck, NY replaced a standard wastewater disposal system with Eco Machine, by John Todd and Ecological Design. The machine mimics the natural processes of water reclamation systems and treats the water using microscopic algae, fungi, bacteria, plants and snails. The filtration process goes through a combination of oxygen-free tanks, wetlands, lagoons and ultraviolet light treatment, and filters almost 200 000 liters of sewage each day (John Todd Ecological Design).

The design was a collaborative effort of experts in wastewater, civil and mechanical engineers, landscape architects and structural designers. The building is carbon-neutral and uses solar energy as the main energy source (Berkebile, McDowell, Lesniewski, 2010).

Figure 7.12.Eco Machine in centre of Omega

Figure 7.13. Water treatment system in Omega

CONTEXT

Seychelles is in the group of the countries most vulnerable to SLR and ocean degradation. Their close relation with the ocean makes them extremely sensitive to the degradation of the marine environment.

The proposal is based on assumptions about a coastal plot on Mahé. It is located between the main road and the ocean. The road goes along the coast and provides access for local community groups, tourists and employees. The design connects three layers of the plot: ocean, beach and palm forest.

The idea for the location is to connect land and water by designing a system of buildings and infrastructure that disperse from the bush through the beach to the ocean.

The beach is a popular destination for both local residents and tourists, and therefore the clear public access is a very much needed.

Figure 7.14. The coastline of Mahé

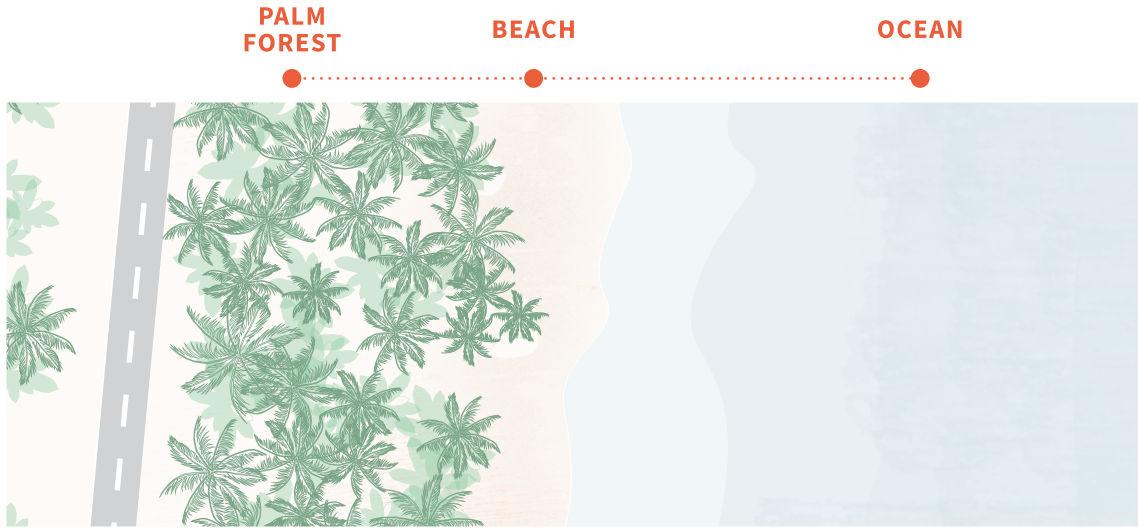


Figure 7.15. Context map

PROGRAM

As one of the most vulnerable countries to ocean changes, simultaneously, Mahé is not prepared in terms of social and economic resilience. Due to their lack of educational resources and other societal challenges, SLR is not prioritized as the most urgent threat.

In addition, the corruption and lack of collaboration render interdisciplinary projects ineffective and reducing their capability to prepare for a wide range of risks.

The design proposes a Blue Education Center that combines research and education functions with a space for collaborative interactions, with the main purpose of strengthening the coastal resilience.

The diagrammatic proposal shows different components and the connections between them, instead of an actual shape of the buildings, materials or aesthetic aspects of each component. The materials should be locally sourced and the construction should be based on local skills and knowledge.

All of the components are separate parts, but they remain strongly connected. This, in the event of failure of one of them, would help to keep the rest undisturbed and allow for the relocation of the damaged function to a different part.

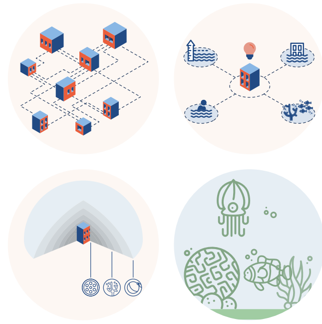
The **research** component includes a necessary research laboratory whose main goal is to extend the knowledge about the coastal environment. The space is design to accommodate marine researchers and provide a space to work closely with local environmental organizations and departments, such as Seychelles' Conservation and Climate Adaptation Trust or The Marine Conservation Society Seychelles. Additional monitoring center, monitors the state of the ocean and to provides data for Division for Risk Management and Disaster Management.

The main **education** component is an on-water classroom that also provides a space for organizing workshops or retreat training meetings. The goal is to provide a space for communication between local residents and researchers. Additionally, the outside beach walkway includes an exhibition space, that is more public and aimed at both, the local residents and tourists.

Spaces enhancing **collaboration** are mostly common break decks and terraces between different components, including one common open kitchen with a recreational space. Additionally, to invite more external collaborators from different fields, such as, Seychelles Sustainable Tourism Foundation or Seychelles Island Foundation, the design includes a big meeting room.

The **regenerative** solutions selected especially for Seychelles include: coral nurseries to restore the natural protection of coral reefs and develop The Blue Economy Knowledge Center's Coral Reef Restoration Project. It also implements a 3D ocean farm as a regenerative alternative for local aquaculture and reduce the dependency on fishing industry.

The system of **protection** is mostly based on Ecosystem-Based Adaptation Project of GOS-UNDP-GEF Programme Coordination Unit. The recovered corals from the nursery are to be replanted to create coral reefs that protect the coasts. Moreover, the buoys from the farm work as monitoring devices to constantly observe the ongoing changes and send emergency signal to the Division for Risk Management and Disaster Management.



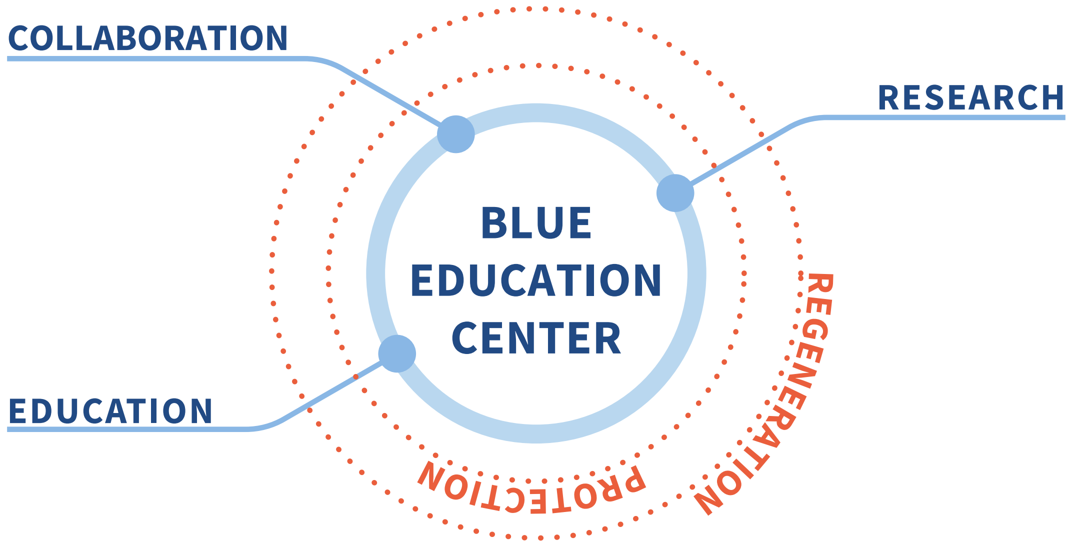


Figure 7.16. Blue Education Center program

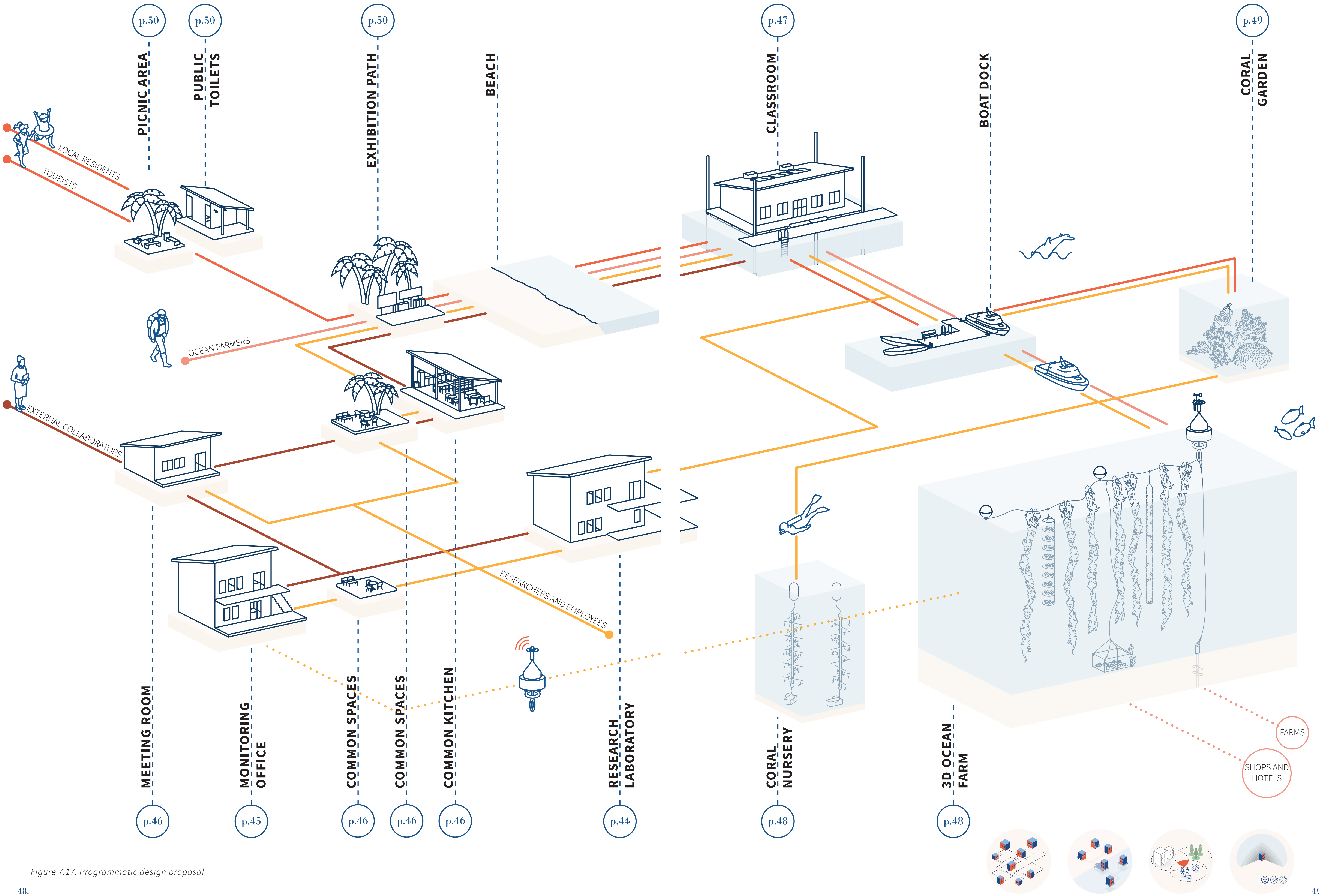


Figure 7.17. Programmatic design proposal

RESEARCH

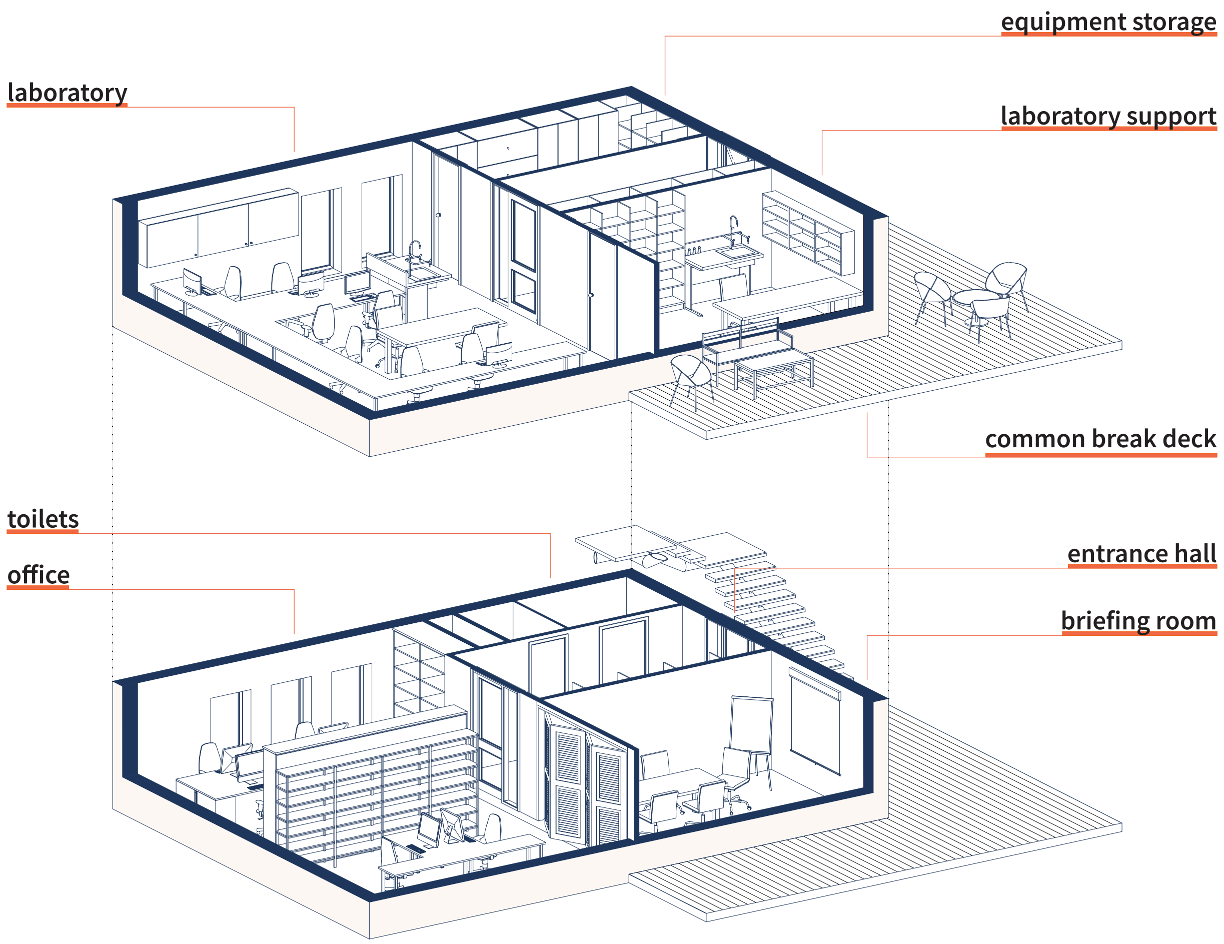


Figure 7.18. Research laboratory

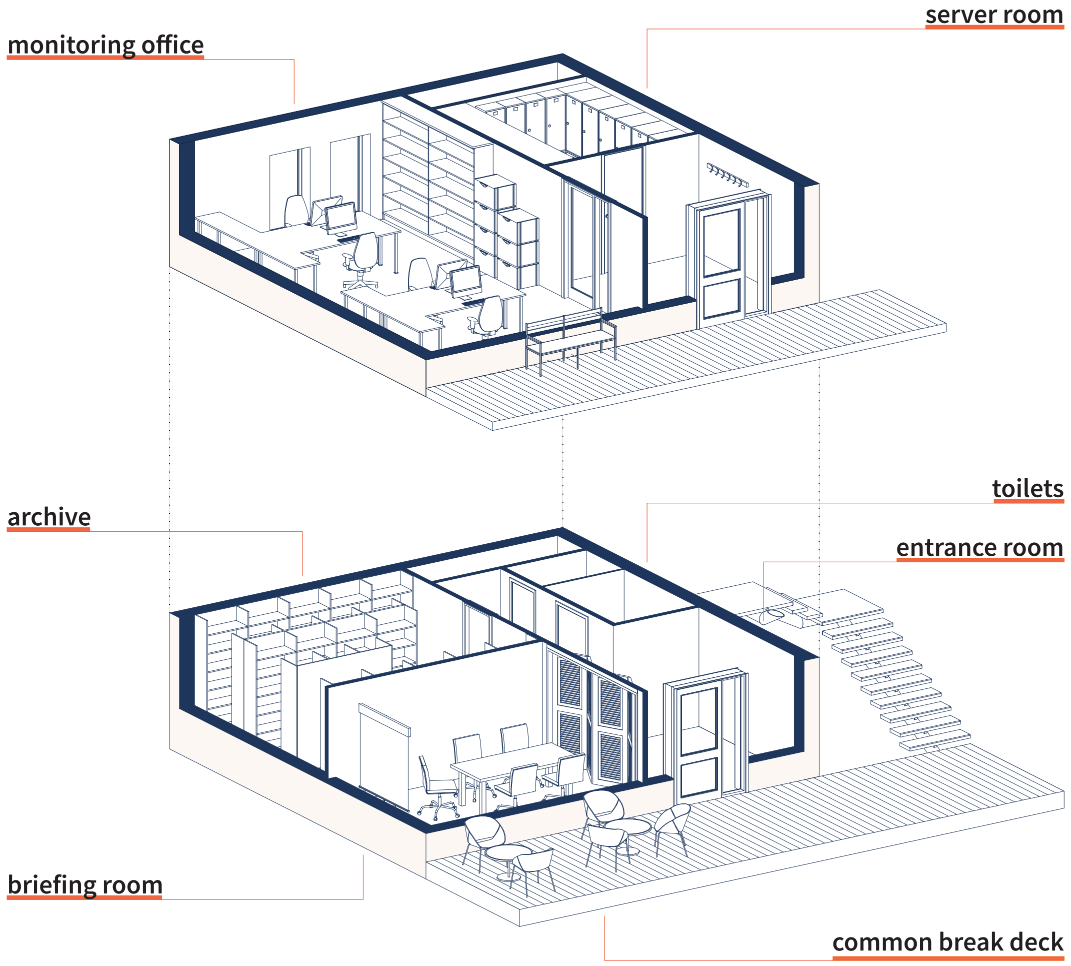


Figure 7.19. Monitoring office

RESEARCH LABORATORY

The research facility provides a space to deepen the knowledge about the ocean changes, protection and regeneration.

The ground floor contains offices and bullpen desks, a briefing room and support rooms.

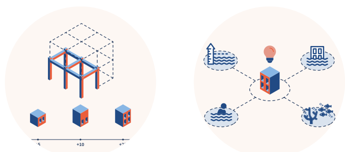
The main laboratory space, with more expensive equipment, is on the first floor for extra precaution in case of flooding. The storage space and support rooms are also on the same floor.

The research building shares a common deck with the monitoring building to make way for informal meetings and build up trust and relationships.

It is also closely connected with a classroom and the big meeting room as those are main ways of spreading the knowledge further and informing the local community.

The main purpose of the research is to deepen the knowledge about the ocean environment, ecosystems and continuous changes. The building has an access to a floating boat deck to allow field studies and encourage learning and experimentation.

The simple layout is easy to adapt to new functions or split into two separate functions on two floors. The simple construction makes it easy to expand over time or restore in case of damage.



MONITORING OFFICE

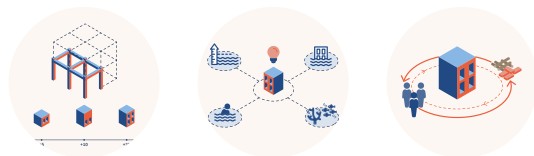
Monitoring and data gathering is crucial in adaptive decision making to provide feedback and allow corrective actions. The monitoring office is a place to collect local and regional data, to analyze the ongoing processes and to make predictions for the future.

The ground floor contains a briefing room and an archive, along with support rooms. The first floor is the main office area and a server room providing technical support.

Tracking is mostly conducted through observation and monitoring buoys that are part of the 3D ocean farm.

The building is linked to the research laboratory and they share a break terrace to strengthen relationships. It allows for interactions and a mutual stream of information, but keeps the separation between the two components at the same times.

To enhance regular knowledge exchange and inclusive planning with the emergency and risk management the building is strongly connected with the meeting room.



EDUCATION

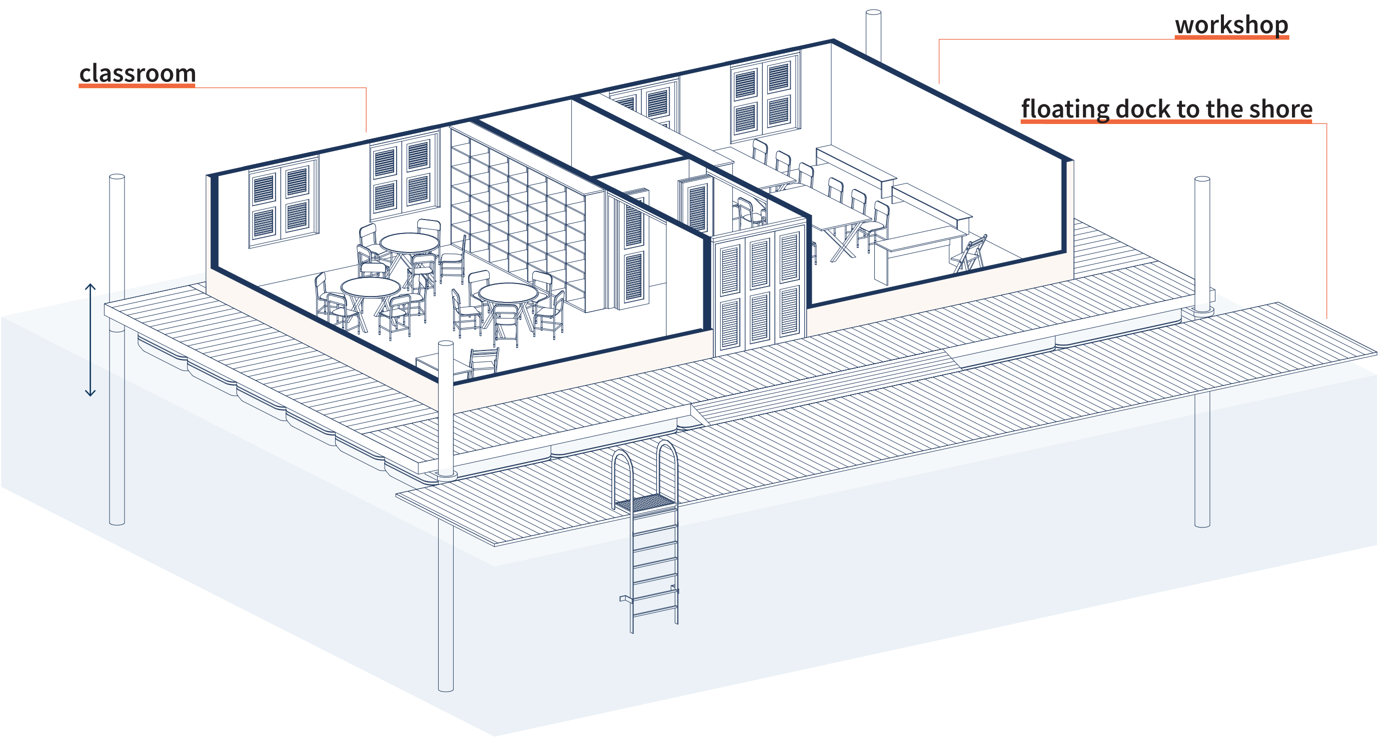


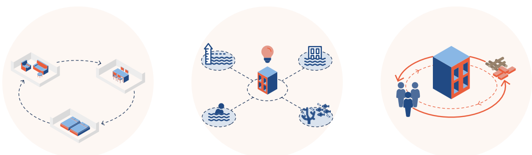
Figure 7.20. Classroom

CLASSROOM

The main education facility is an amphibious classroom on the water, fully adaptable to the changing sea level. The construction of the building is elevated on stilts and its uses empty recycled jugs to float. To increase self-sufficiency the class building is using natural lighting and natural ventilation through high windows. Later in the development it would be advisable to implement a rainwater harvesting system and solar panels.

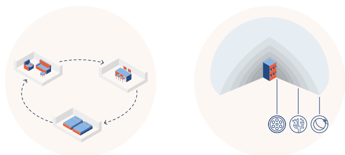
The main function of the classroom is to connect the community with the researchers and create an informal place for education. Everyday use is to organize workshops and classes for different stakeholder groups, for example school kids or visiting researchers.

In the evenings it provides a space for community meetings, which would strengthen social resilience.



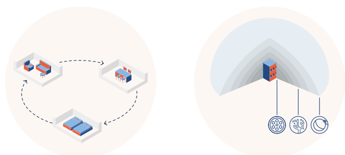
RETREAT TRAINING CENTER

With a developing plan for a retreat the classroom would also be used as a retreat training center (fig. 7.21) to prepare local residents for the worse case scenario. The retreat plan reduces the trauma of urgent displacement.



EMERGENCY SHELTER

Moreover, in case of emergency it could be used as a shelter (fig. 7.22) for those whose houses were destroyed during a tropical cyclone or other extreme events.



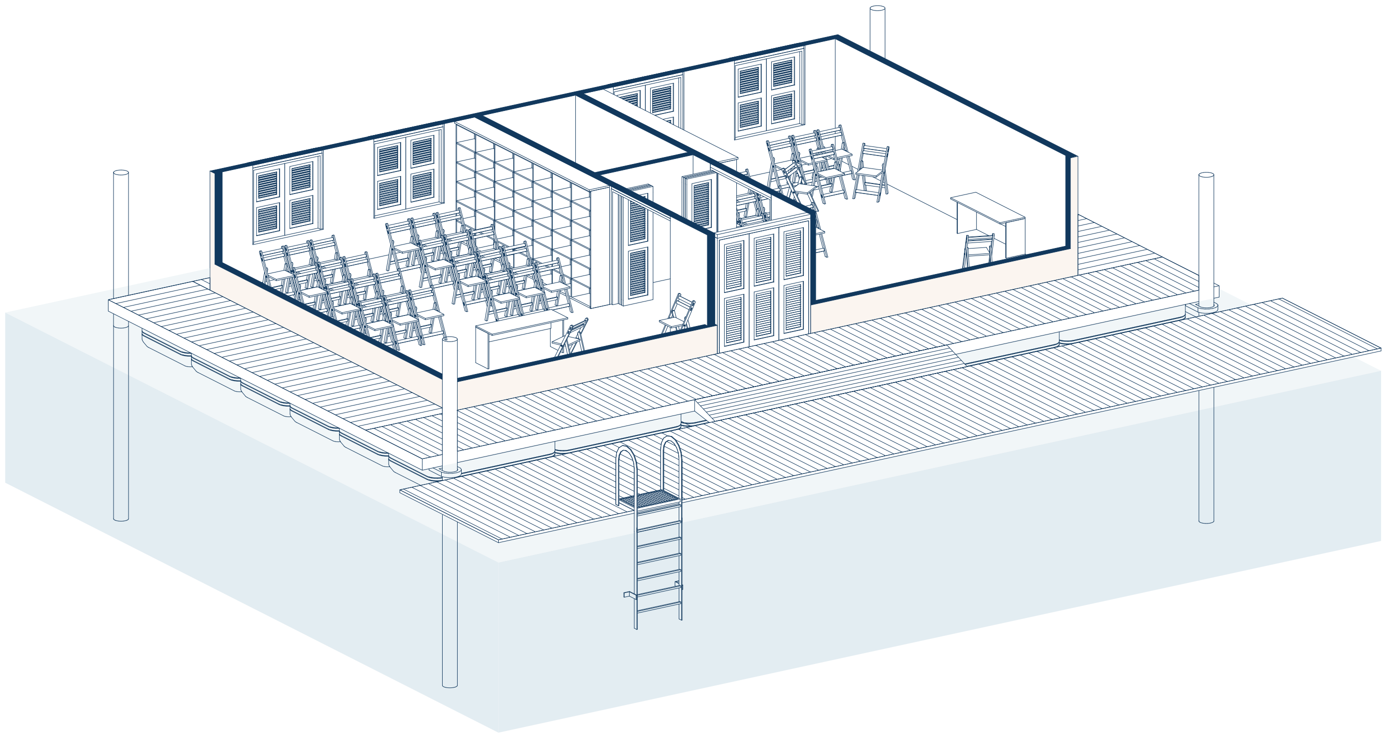


Figure 7.21. Variation 2: Retreat training center

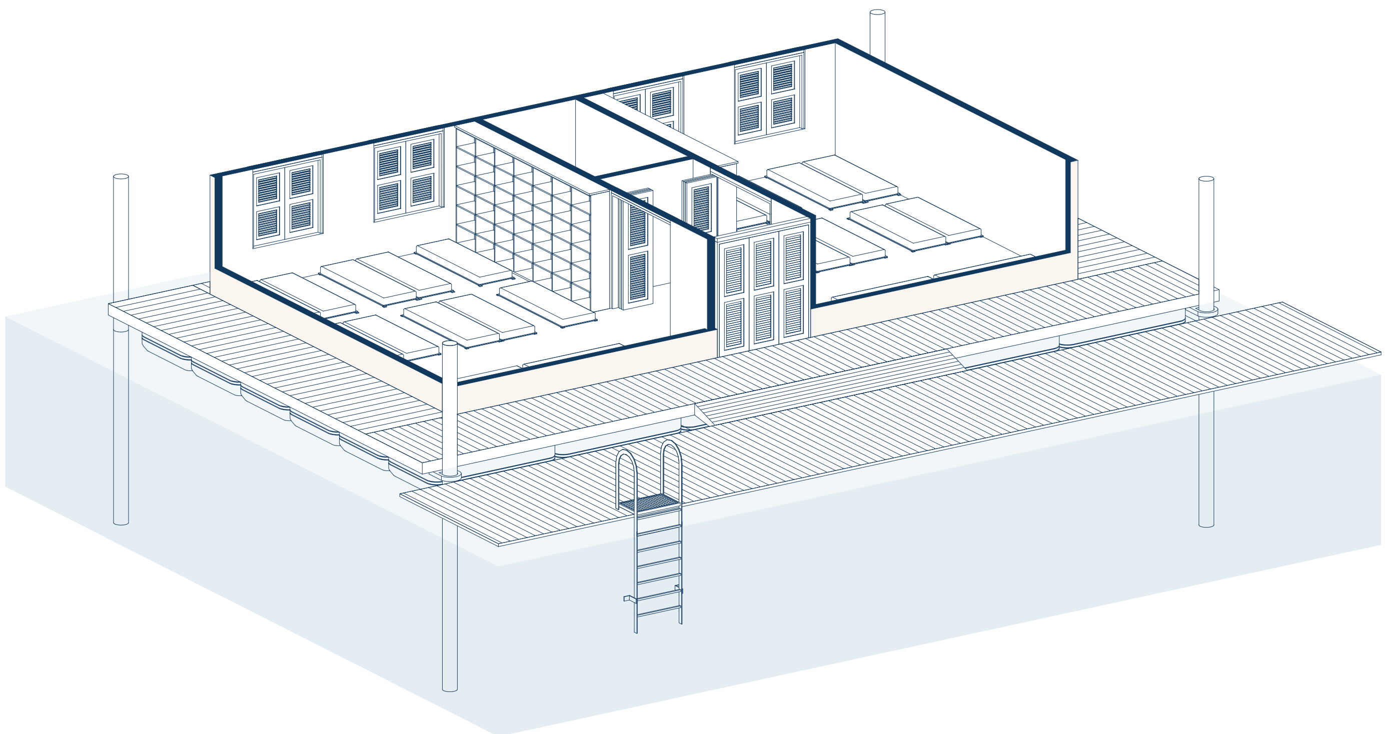


Figure 7.22. Variation 3: Emergency shelter

COLLABORATION

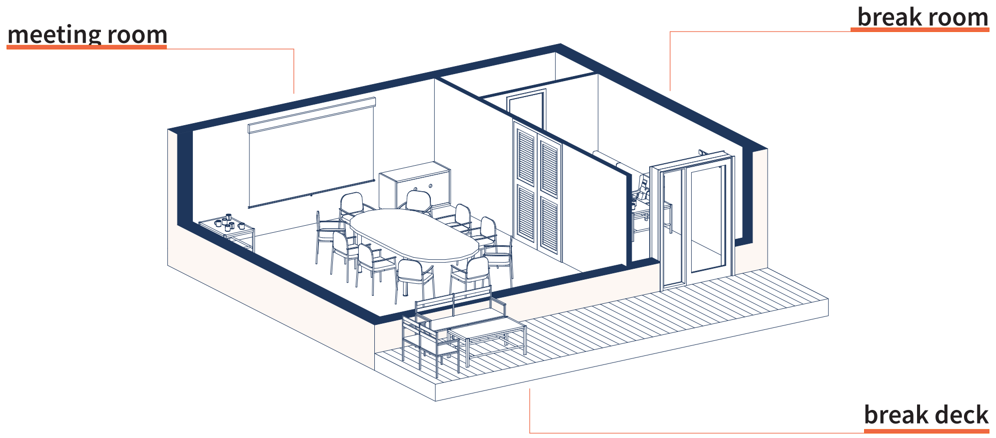


Figure 7.23. Meeting room

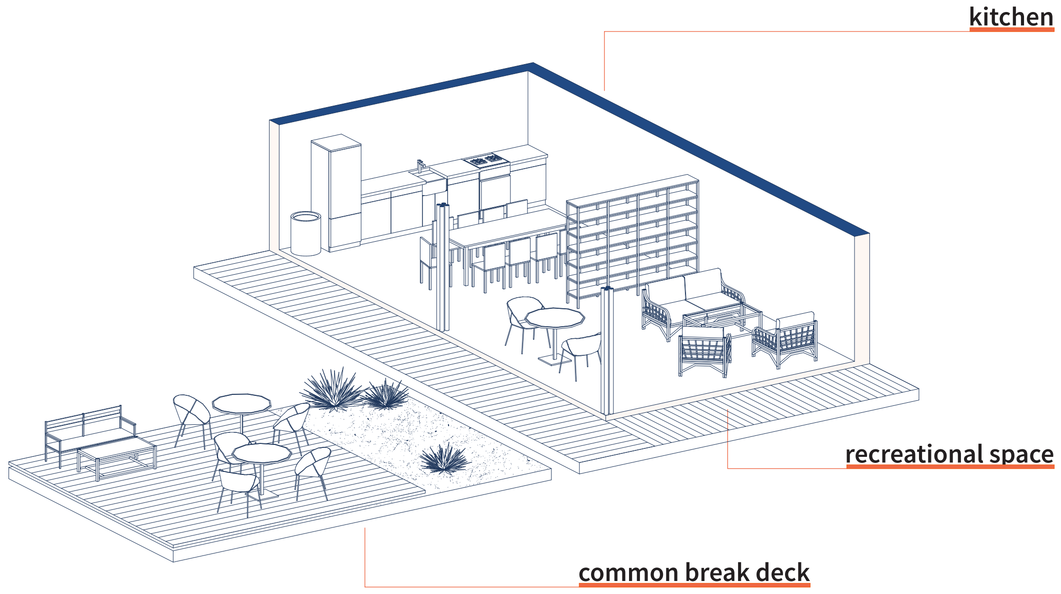


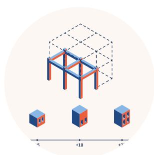
Figure 7.24. Common spaces

MEETING ROOM

One of the biggest challenges on Mahé is the lack of collaboration and a huge level of corruption due to a non-transparent system. A big meeting room would encourage an interdisciplinary approach and invite different stakeholders to exchange knowledge, concerns and ideas, to bring a more holistic approach into planning future developments.

The meeting room a place to connect on-site employees with external collaborators, therefore it is located close to the main road and it is easily accessible from the entrance.

The easy layout contains one meeting room to organize small conferences and facilitate projects across the entire island. It has external access from the main street and is closely connected with the monitoring office and laboratory.
The building is flexible and could be easily extended over time when demands grow and there is need for a second conference room.



Externals collaborators include:

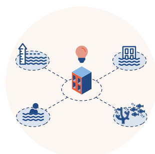
- National government
- Local government
- Environmental organizations
- Emergency and risk management
- Fishing authorities
- Tourism foundation
- Planning authorities
- Education sector

COMMON SPACES

All of the buildings have access to different common spaces to encourage social interactions and help with building strong social networks. The spaces are designed mostly for the people working on this site. However because of the open character of the place, the external collaborators have access to some of places, including the kitchen and recreation area.

The heart of the common spaces is a half-open kitchen connected with a recreation area. The goal is to provide a space where at least once a day all of the employees, especially researchers form the laboratory and employees from monitoring office, can meet to build up trust and relationships. Strong social network and informal exchange of knowledge builds up self-organizational abilities and strengthen resilience.

Additionally, smaller common spaces are located between buildings, such as shared decks with benches and tables, for informal meetings and coffee breaks.



PUBLIC ACCESS

All beaches in Seychelles are public property. The beach is visited by both local residents and tourists and it is important to keep the balance between those groups. The main entrance to the Blue Education Center is open and the space is reinforcing its inclusive nature.

The design provides some basic infrastructure to enhance waterfront recreation but keep the natural environment protected.

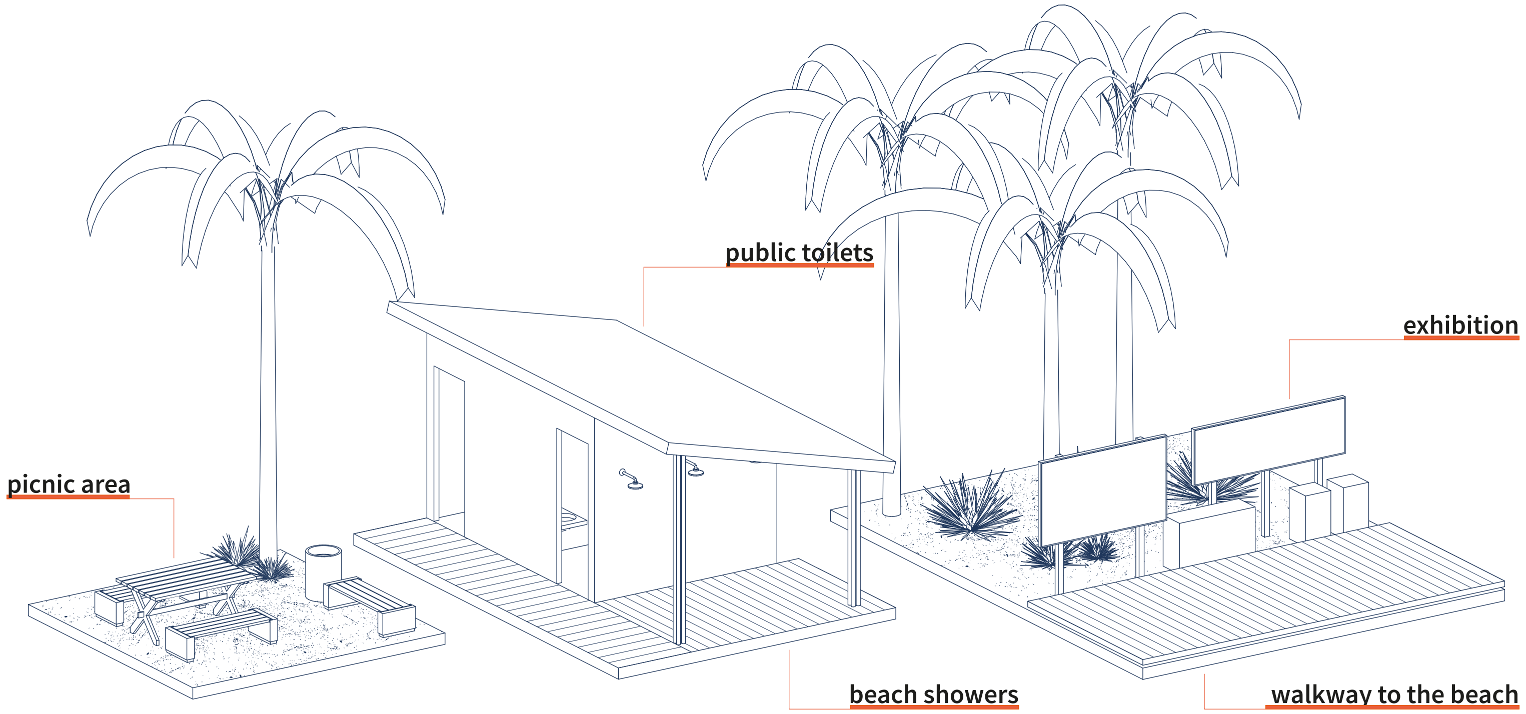
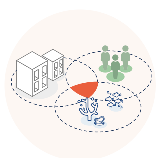


Figure 7.25. Public facilities and exhibition path

PUBLIC FACILITIES

A system of wooden walkways through the bush connects the main entrance point, from the road, with the sandy beach. Basic infrastructure located in the bush, such as picnic tables, sitting areas and bins, creates an inviting space to have a lunch break and discourages the people from damaging the natural environment by littering.

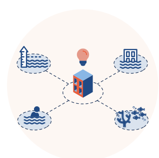
The entrance building contains public toilets and beach showers. The building is clearly visible from the walkway and there is an information sign visible from the beach. The structure of the building is based on a grid for flexibility reasons so that it could be extended in the future.



EXHIBITION PATH

The exhibition path is a part of the wooden walkways. Along the walkway there is a small exhibition space to display information about Seychelles' natural environment. The displayed information will be changed from time to time and will provide updates about current projects.

The main target group for the exhibition are tourists visiting the beach. The goal is to inform them about the impact they have on the coastal ecosystem, for example, it explains what "responsible snorkelling" means. The goal is to encourage people to make more informed choices and discourage picking up corals and littering on the beach.



REGENERATION

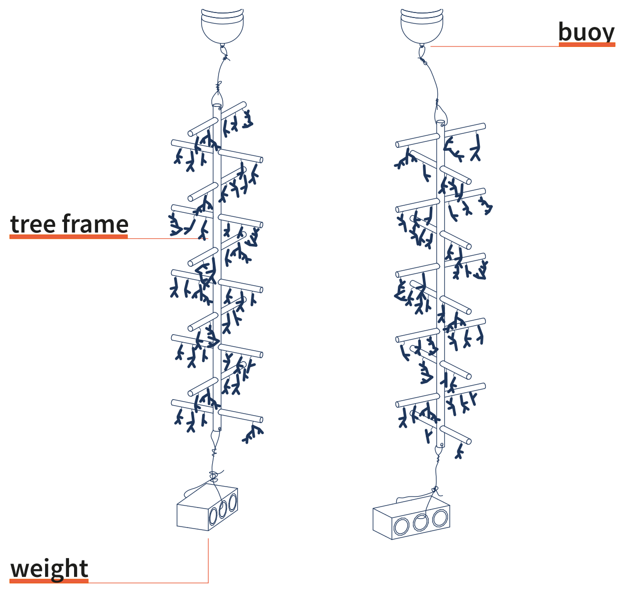


Figure 7.26. Coral nursery

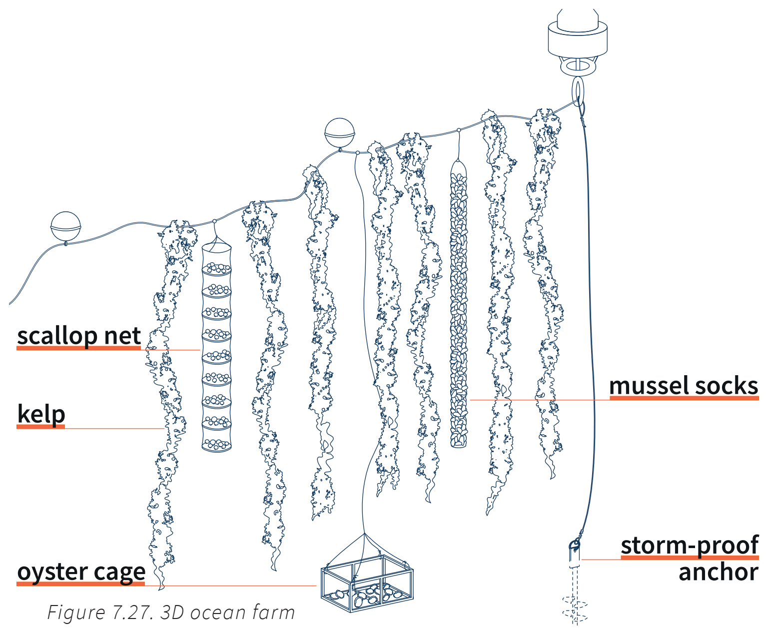


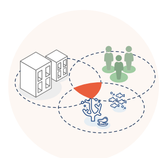
Figure 7.27. 3D ocean farm

CORAL NURSERY

Coral bleaching is widely damaging coral reefs in Seychelles. As one of the responses, Coral Reef Restoration Project is gaining recognition not only around the country but also reaching out to other countries, such as Australia or Maldives, that are dealing with coral bleaching.

Coral restoration creates a new natural habitat and helps to regenerate existing ecosystems. New underwater coral nurseries create a space where the broken coral, that would not survive rolling around on the seabed, can recover and mature to their colony size. Coral fragments hang from tree frames. The weight keeps the construction on the seabed but allows it to move along with the ocean flows. Buoys attached on the top keep the frames in a vertical position.

The proposal includes creating places for a coral nursery to sustain local skills and allow for further development of the project. Moreover, divers and scientists would conduct workshops and lectures about the marine environment: how our lives are dependent on it and how to protect it. It could also encourage kids and teenagers to stay in schools and continue education.



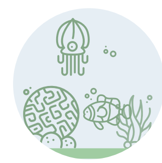

3D OCEAN FARM

Fish, mostly tuna, is the main export product of Seychelles (National Bureau Of Statistics, 2019). It is also one of the biggest, along with chicken, sources of protein in the local diet. When the fish stock significantly drops , the community will face a difficult dilemma between economic development and food security.

Introducing more polycentric ways of ocean farming reduces dependency on one kind of fish and increases biodiversity. 3D ocean farming is a model of a vertical farm that combines seaweed and shellfish. Kelp forests and mussel socks are hanging on long ropes, spread out between buoys, making little impact on the water surface. The entire system is attached to the seabed with a storm-proof anchor.

Harvested kelp and scallops would provide food for the local community or be distributed to hotels and restaurants. Kelp could also be used to fertilize agriculture farms.

3D ocean farming is characterized by minimal input as it does not require freshwater, feed or fertilizer. It has a relatively low barrier to entry, therefore, it provides an accessible business model that creates new jobs.



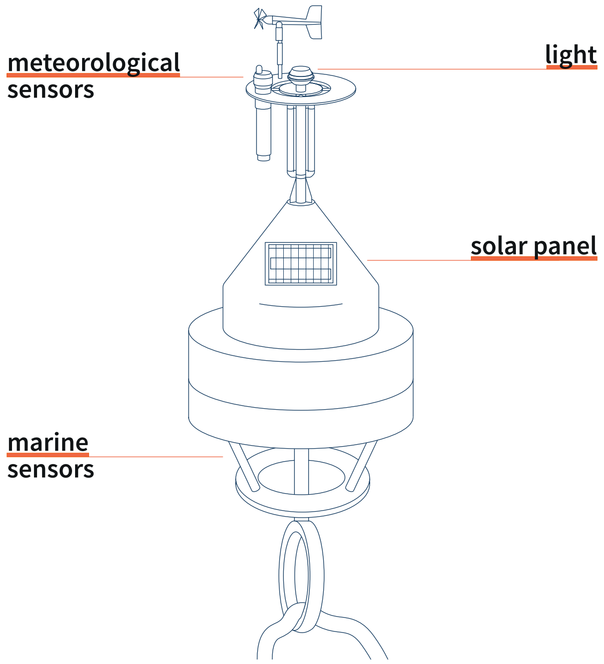



Figure 7.28. Monitoring buoys

MONITORING BUOYS

The biggest buoys from the ocean farm have sensors gathering data about the ocean state, meteorology and water quality. By integrated GPRS they send information back to the monitoring office. Later this data is used to create predictions and prepare prevention plans.

In case of extreme fluctuation, buoys send additional signal directly to the emergency and risk management units for quicker reaction and response.

The buoys are strong enough to withstand extreme sea events, non-corroding and easy to maintain.

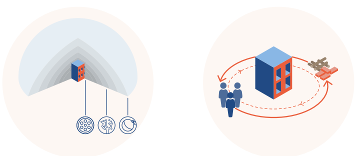


Figure 7.29. Coral gardens

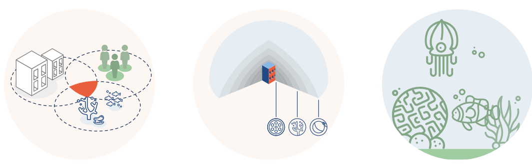
CORAL GARDENS

Grown, about 10 cm wide, coral fragments from the coral nursery are later replanted in shallow coastal zones to create coral colonies that later will grow into coral reef.

Coral has an important impact on coastal resilience by protecting the coastline from waves. Building natural protection is more cost-efficient than building artificial structures and more environmental friendly than building walls.

Coral reefs, even though they cover less than 1% of the ocean floor, have a high share in marine biodiversity. It is assumed, that they provide food and shelter for a quarter of all ocean species (Smithsonian, ocean.si.edu). Therefore, restoring the coral reefs will increase biodiversity.

Reef recreation value is enormous, especially for communities highly dependent on tourism. Coral reefs will attract more tourists and generate income to strengthen economic resilience. Together with the educational facility they will teach responsible snorkelling.



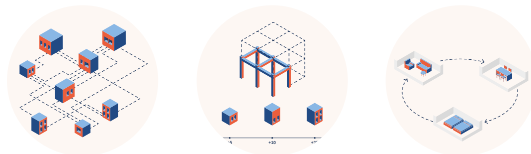
Compound design allows for phased planning of development. Each step would provide new components of the system to stagger the expenses and allow corrections. Building consecutive parts of the complex design follows the funding and reduces the perspective of an unbearable economic effort.

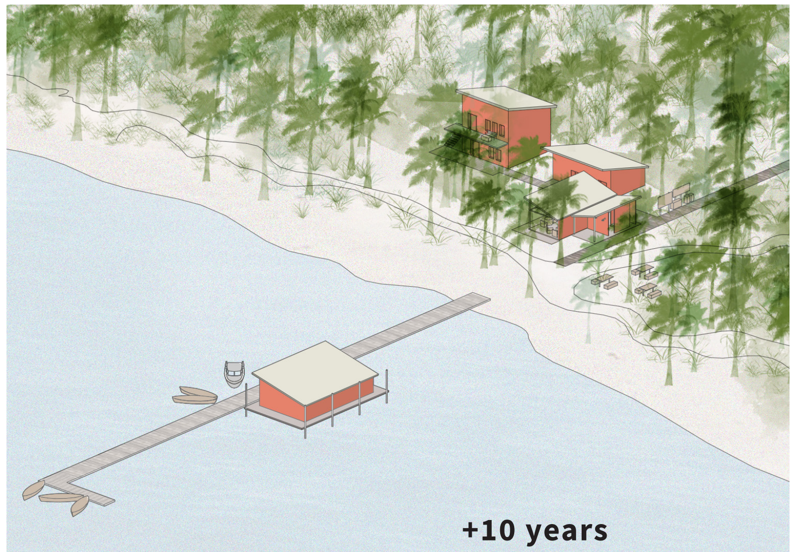
+5 years:
- meeting room
- coral nursery
- public infrastructure
- classroom

+10 years:
- monitoring office
- common spaces
- part of ocean farm

+25 years:
- research laboratory
- second classroom
- extended ocean farm

The planned order of subsequent phases will evolve and change to adapt to the growing needs, the dynamic environment and new skills.





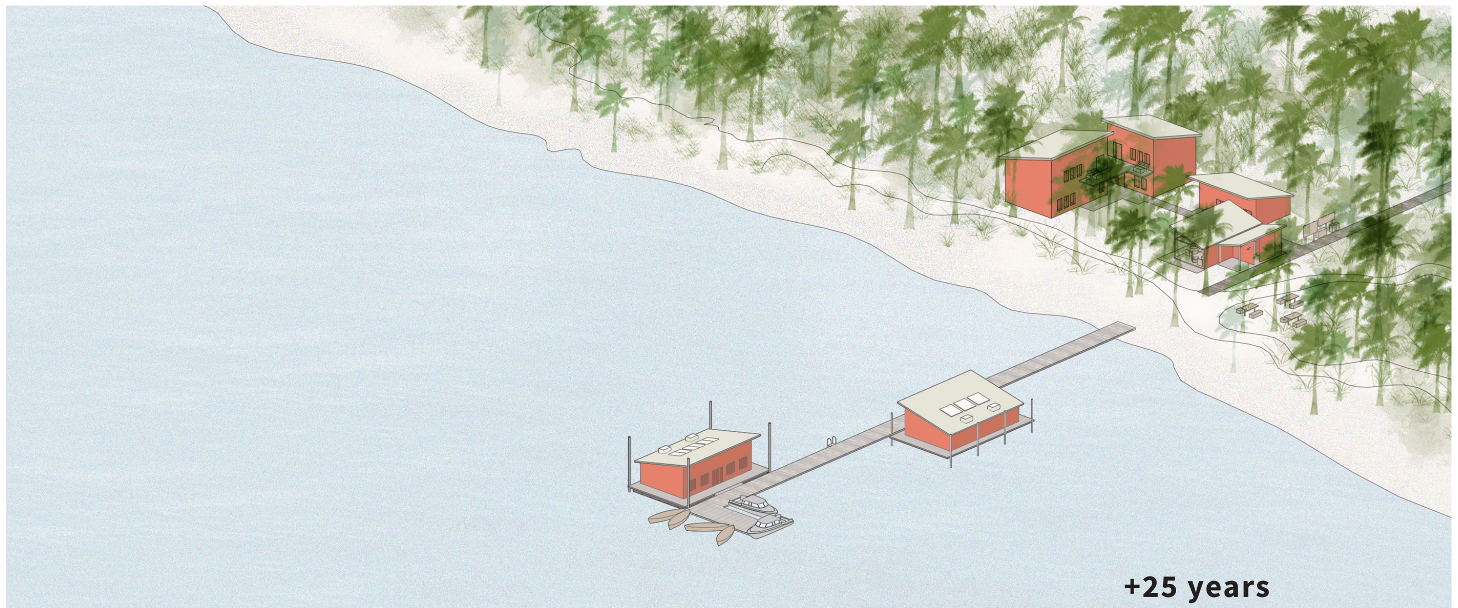


Figure 7.30. Consecutive phases of the project

08

FUTURE POSSIBILITIES

DESIGN STRATEGIES NETWORK

The object of the thesis was to create design strategies to reduce vulnerabilities of coastal communities and strengthen their resilience.

The presented guidelines help to build a safe environment for the people and natural ecosystems to thrive, despite the threats of the risks related to ocean change.

All of the design strategies aim at strengthening resilience. Some relate more to the construction of the building, others are related more to the function. Most of them implement each other.

For example, polycultural solutions have a positive impact on biodiversity and therefore enhance the holistic means of the design. Raising awareness will increase knowledge and will lead to more advanced self-organization skills. The compound structure makes it easier for each part to be flexible and adaptable.

The different strategies are not applied in equal proportions and should be dictated by local context, risks and abilities. The strength of those strategies, following the theory of resilience, comes from their complexity and the connectivity between them. Therefore, to achieve maximum capability all of the strategies need to be applied.

Design strategies extracted from research:

- Compound structure
- Comprehensive approach
- Multi-layered protection
- Flexible construction
- Adaptable layout
- Raising-awareness function
- Self-organized design
- Holistic means
- Polycultural focus

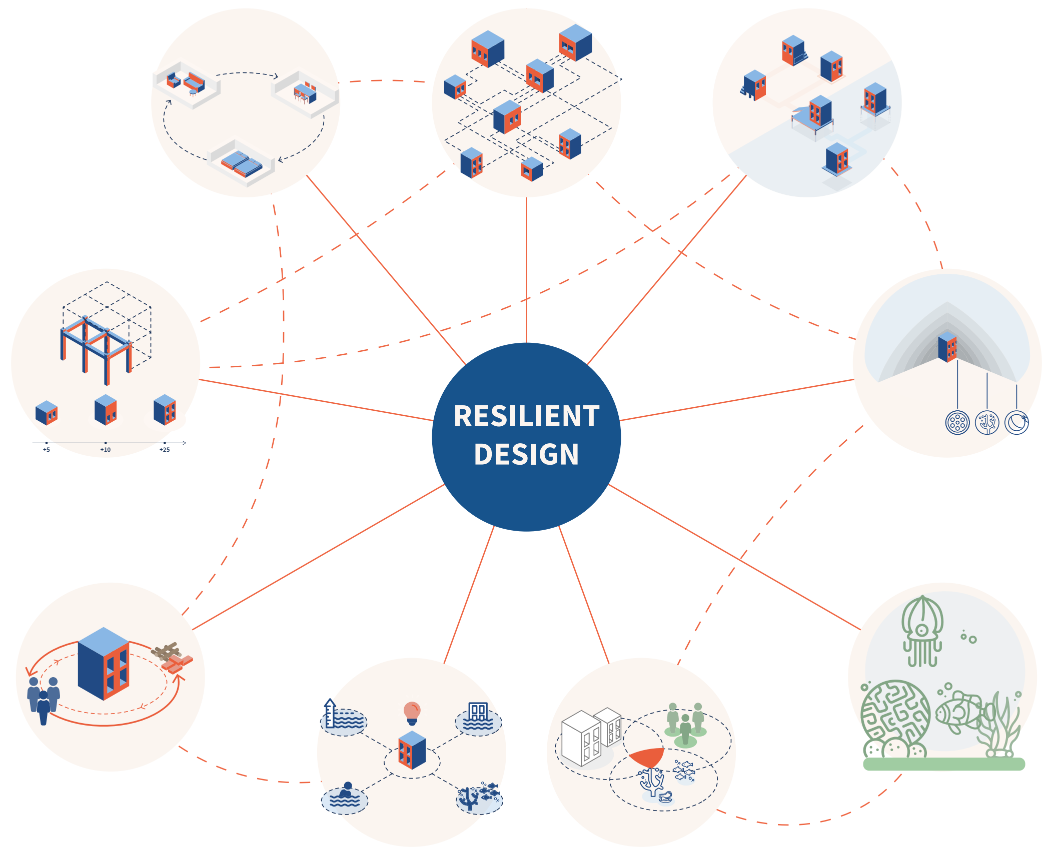


Figure 8.1. Interconnection of design strategies

IMPLEMENTATION POSSIBILITIES

The main intention is to reduce the risks by design: the Blue Education Center facilitates research, education and collaboration and is integrated with regenerative solutions and protection from sea level rise risks.

The design is a programmatic illustration of a building following design strategies for resilient architecture. The specific context of the location has not been included in the design to make it more universal and easier to implement in other case studies or coastal communities around the world.

Following design strategies and adding local context of, for example Rotterdam, the proposal would change its form but keep the complexity and connectivity of the system.

One of Rotterdam's biggest risks is damage to the existing infrastructure, for example housing. Their biggest strength is long history of monitoring and research. The Dutch proposal would not then need to focus on offices and a laboratory but rather building different kinds of housing. Restoration of coral reefs could be exchanged for installing living seawalls along the canals to build up biodiversity.

The design for Staten Island would focus on continuing to create a new habitat for oysters and clams, but for example change the public beach entrance, connecting perpendicularly the road and the beach, into a coastal public waterfront walkway. The path along the coast could include a classroom and workshop space, and different activities, such as a sustainable fishing center or playground that is shaped to mimic the oyster reef.

The overall shape of the structures depend on the local needs, but has to be inclusive and enhance collaboration.

RISK REDUCTION

Despite challenges with access to the informations about the local context, due to difficulties with contacting stakeholders and a cancelled field-study trip, the presented proposal is designed to reduce exposure to the risks caused by ocean change.

Figure 8.2 presents a speculative analysis of the design's influence on ocean change risks.

Public areas sustain social activities and welcome tourists, which for many coastal communities is one of the biggest sources of income.

Clear access to the beach enhances accessibility and maintains livelihoods.

The classroom creates a space for community meetings and provides a connection between local knowledge and expert knowledge.

Restoration of the coral reef environment increases biodiversity and reduces habitat degradation. Furthermore, it creates a space for recreation and constitutes a tourist attraction.

The monitoring office reduces casualties by closely monitoring and analyzing the changing environment and enabling the emergency procedures.

Common spaces enhance knowledge exchange, both formal and informal.

The research laboratory reduces habitat degradation and biodiversity loss by deepening the knowledge about the marine environment and exposing potential areas for improvement.

The coral nursery restores coral fragments and regenerates the bleached coral colonies. It also provides new habitat for many marine species.

The ocean farm provides a polycultural model of farming that enhances biodiversity. It provides an alternative food source. Additionally, selling kelp and shellfish to hotels and restaurants generates income.

Despite the fact that the meeting room does not directly reduce ocean-related risks, it is one of the most important parts of the proposal, that enables processes and growth. The building indirectly reduces the risks by strengthening the effectiveness of the other components.

The speculative effects of the design proposal on reducing risks, highlight the potential of architecture to influence the exposure of coastal communities.

Future development of the topic should push that correlation even further and present the importance of architecture in the context of Disaster Risk Reduction.

Increased coastal hazard, due to climate change, should be meet by global effort to develop new solutions to reduce the exposure of coastal communities.

DISCUSSION

This master's thesis links the risks related to sea level rise and ocean degradation with the vulnerabilities of coastal communities. Solving the challenge of rising sea level is an impossible task. It is, however, possible to reduce the vulnerability of the coastal environment by increasing resilience of the complex system of social, ecological and economic actors. We cannot, and should not, stop people from living on the coasts, but we can encourage them to take more informed actions and increase preparedness. This thesis is a comment in the discussion on how to create coastal spaces without sacrificing the safety and health of the natural environment.

Constantly changing circumstances require a critical perspective and open discussion about our defense strategies. First of all, about the importance of climate change impact in the process of planning new developments.

Regarding the research question of this thesis, architecture plays an important role in strengthening the resilience of coastal communities by increasing their preparedness.

The research methods used revealed the importance of learning and education, which help communities to understand the environmental process and the causes of disasters. Additionally, collaborative actions enable an open discussion about threats and opportunities and provide wider knowledge about potential risks.

The delimitation of the thesis focused on environmental risks and their impact on coastal communities, rather than the technical aspects of resilient constructions. Therefore, the thesis did not investigate local typology and materials on Mahé.

With more time to develop the thesis, and different circumstances, I would focus on the specific local community and investigate closely the interdependencies between different actors: humans, ecosystems and built structures. The next step of the research would include interviews with stakeholder groups and site visits. Based on local analysis, the design model should be adapted directly to the specific site.

To highlight the importance of the coastal communities in to the process of designing for risk reduction, a revised and developed design model could be compared with the design proposal presented in this thesis in chapter 7. The differences between two models and overlapping them with ocean change risks could also expose missing stakeholder groups that should be included in future developments.

In the next step of the thesis I would focus on more technical solutions and types of constructions that could be used for different components. The solutions would rely on local skills and materials, and participation from local builders would be essential. It could also include research on water treatment solutions and using ocean tides as a source of energy.

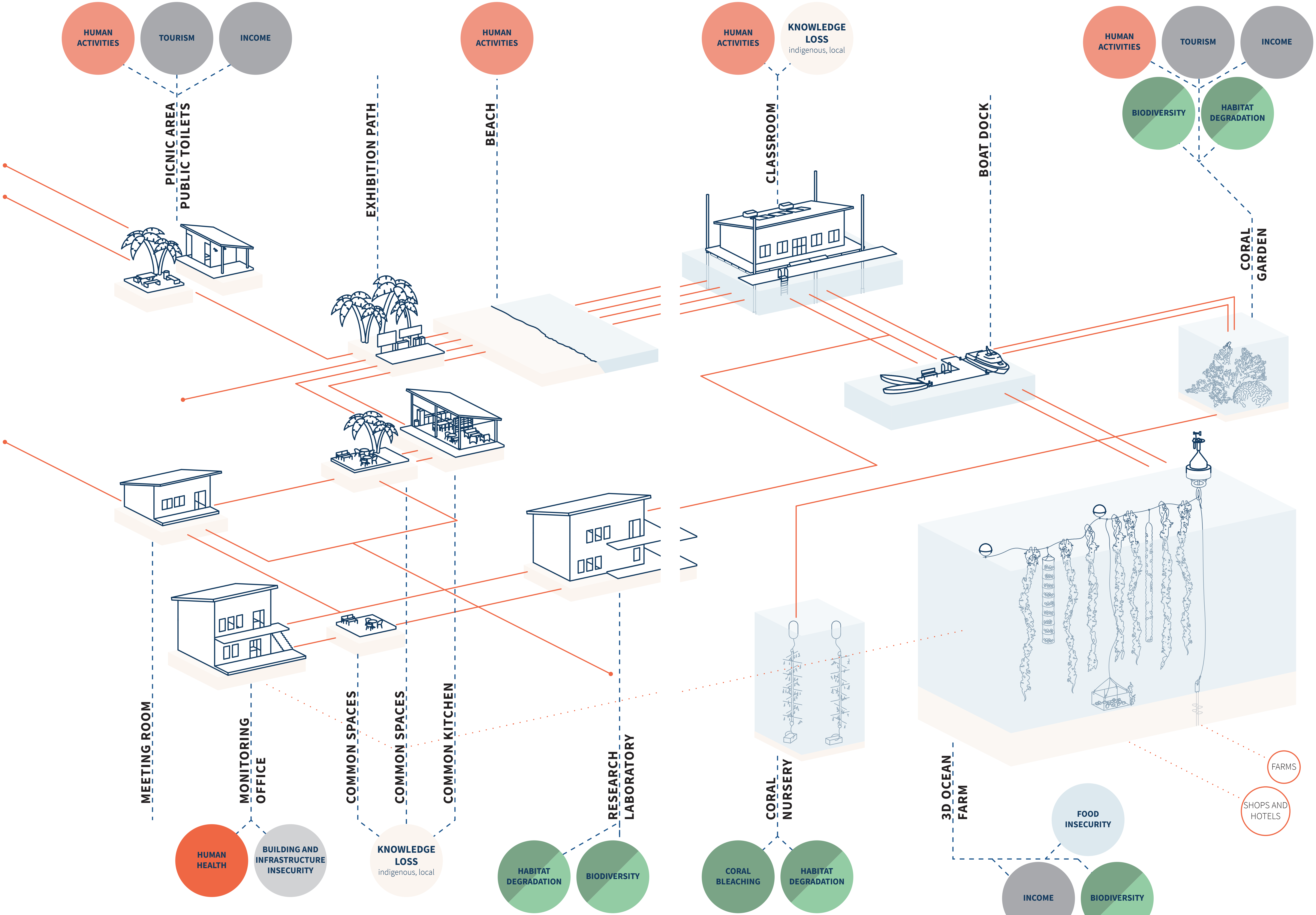


Figure 8.2. Design's impact on ocean change risks

MANIFESTO

1.
Rising sea level is happening now.

2.
Denial will only increase the loss and weaken resilience.

3.
Living closer to the ocean means a bigger responsibility to protect it.
Not bigger damage.

4.
There is an urgency to restore maritime biodiversity, natural flows and reduce pollution. It will be rewarding for all of us.

5.
Every person deserves a safe shelter and access to food and water.
No matter what are the circumstances.

6.
Global effort must be focused on the most vulnerable areas.

7.
Ocean protection is not against economic growth and development.
On the contrary.

8.
Longer preparation does not mean better preparedness.

09

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Figure 3.5. Purpose of Living Breakwaters. Adapted from Gendall, J., Bisker, J., Chester, A., Eisenberg, T., Davis, S., Ovink, H. (2015). *Rebuild by Design.*

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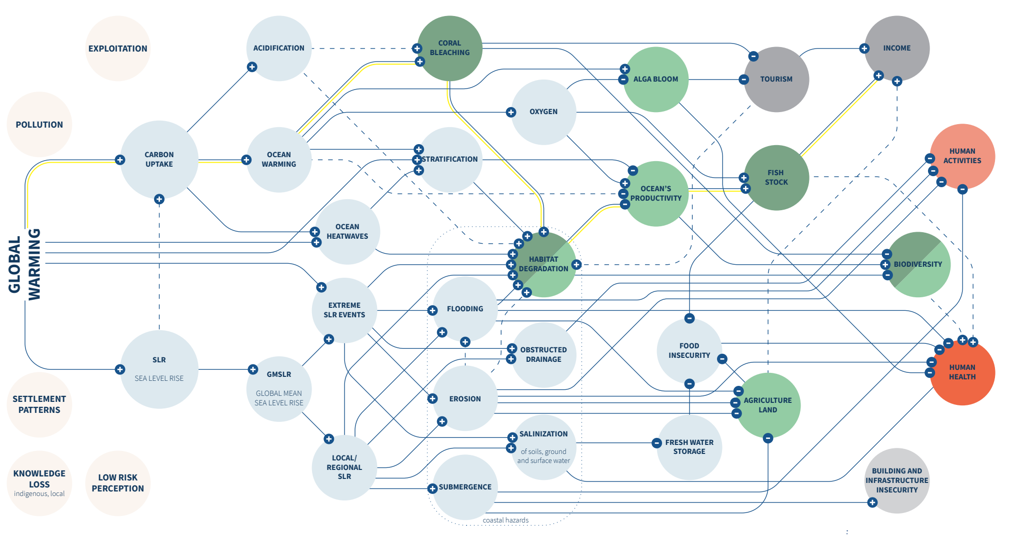
APPENDICES

APPENDIX A
COMPOSITIONS

RESEARCH

How can architecture strengthen the resilience of coastal communities to sea level rise and reduce their vulnerabilities?

GLOBAL RISKS ASSOCIATED WITH OCEAN CHANGE



Slow-onset ocean changes and sea level rise create a chain reaction of risks, directly threatening coastal communities.

EXAMPLE: CORAL BLEACHING

Global warming is causing increased carbon uptake by the ocean, which results in higher acidity of the water. High water temperature is a direct cause of coral bleaching, as it loses the symbiotic algae, the zooxanthellae, that covers its tissues. Bleached coral colonies have a lower capacity of reproduction and are more vulnerable to other threats. Increased acidity of the seawater prevents corals from building their calcium carbonate skeletons and in severe acidification it could lead to damages of the existing skeletons and the destruction of already existing coral reefs. That leads to an overall degradation of the habitat that coral structures create for many ocean species, both in terms of food and shelter. That disturbance of the natural ecosystem, accelerated by stratification, limits the ocean's productivity and reduces the overall fish stock. Most of the coastal communities, especially SIDS, depend on marine ecosystems services and the fishing sector is their main source of income, both in terms of private income and national export product. Moreover, for many SIDS fish is the main source of protein in their everyday diet and lack of it could indirectly lead to deterioration of health.

Ecological Risks: Flora, Fauna
Social Risks: Activities, Health
Economic Risks: Income, Infrastructure
Direct impact
Indirect impact
Non-climatic drivers

CASE STUDIES OF COASTAL DEFENSE STRATEGIES

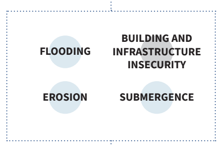
ROTTERDAM

326 km² (117 km² covered by water)

651 446 - population (4% of country's population)

3 087/km² - density

- High value of research
- Interdisciplinary approach
- Lack of natural environment protection, focus on infrastructure and people



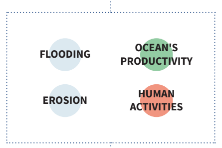
STATEN ISLAND

152 km² - third biggest NY borough

476 200 - population (5% of NYC, 2,5% of NY)

3 132/km² - density (lowest in NYC)

- In-water protection with onshore interventions
- Coastal resilience co-dependent with habitat improvement and engagement from community
- Big focus on building social resilience



MAHÉ

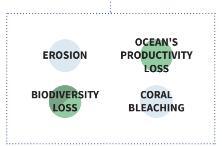
157.3 km² - biggest island of Seychelles

85 300 - population (88% of country's population)

111.3 km - coastline

Victoria - capital

- Focus on ecosystems restoration
- Low level of research and education
- Lack of collaboration, non-transparent structure
- Due to other socio-economic challenges SLR is not prioritized



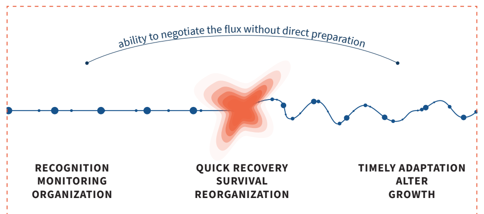
In Rotterdam, the biggest issue is a threat to existing infrastructure if the Maeslant Barrier were to stop providing protection.. The Dutch model does not provide positive environmental impacts, which will have catastrophic outcomes for the natural ecosystems and, consequently, for the people.

Staten Island shares the threat to the existing infrastructure, which is complemented by danger to human activities along the coastline. However, their layered proposal is not dependent on one solution to protect the entire community.

Seychelles islands are indisputably the most vulnerable ones among the three cases, but their commitment to protecting the natural environment is profound.

Despite differences in location, social context and economic status, all of the studied cases are coping with the same challenge to climate-proof their communities and to reduce global warming. As climate change creates most in the first place, it is impossible to try to solve one part without the other. It is necessary to treat those two challenges as one, to reduce the vulnerabilities and strengthen coastal communities.

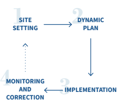
RESILIENCE



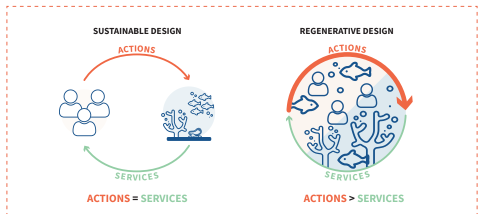
In the context of this thesis, resilience stands for the ability to absorb adversity, adapt and recover from extreme sea events.

This strength comes from the complex interconnections and dependencies between components. When one or more connections are damaged, the system is able to reorganize and sustain its functions and slowly adjust. Diversity within the system helps with the reorganization ability and the response to interruptions.

In order to prepare for the uncertain future it is recommended to follow the adaptive decision making process.



REGENERATION

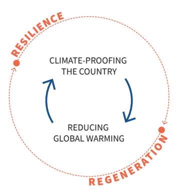


To achieve social and ecological resilience it is crucial to conceive of the natural environment and humans as one system rather than two supporting organizations.

Regenerative design is based on the integration of social and ecological subsystems. The structure eliminates the distinction between winners and losers in the exchange of actions and services.

One inclusive system encourages more positive actions that are beneficial for all. The cohesion allows for wider perspectives of growth instead of seeing actions and services as a trade that could be profitable for one side only. Moreover, the indirect exchanges can bring more value that is hard to measure using the typical concept of trade.

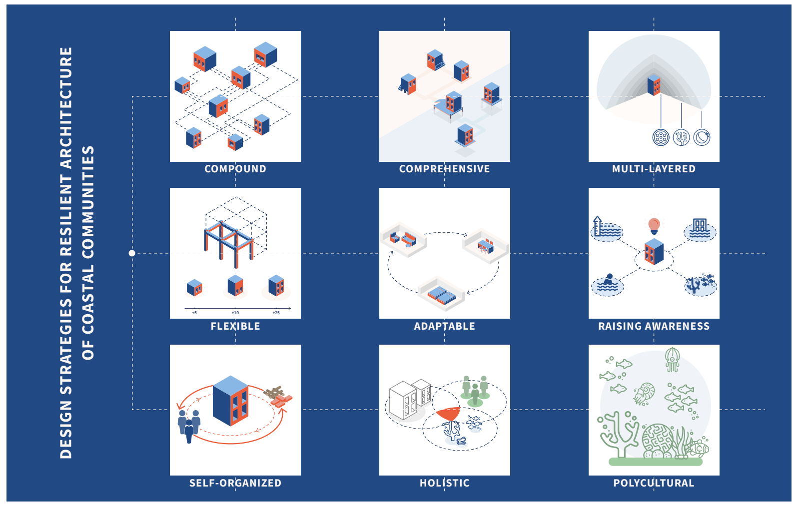
The regenerative approach focuses on processes rather than building a product or capital. The goal of regenerative design is to support the positive co-evolution by building "capability", not infrastructure itself.



Both, resilience and regeneration, are based on complexity and connectivity, rather than linear or central organization. Both support inclusiveness and diversity, rather than monoculture, to improve the capacity of their processes.

Climate change is unstoppable, but instead of falling into despair of the hopeless future, we need to reduce the trauma. Change can be good, however, we need to be proactive about it so it will not bring more degradation and suffering. Through collective efforts of strengthening resilience and applying regenerative solutions we could significantly reduce the vulnerabilities of coastal communities.

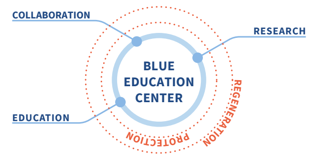
DESIGN



Research resulted in nine design strategies for resilient architecture for sea level rise. Those guidelines are for all coastal communities struggling with ocean changes. Each one of the rules can be applied in the design process and is adaptable to the scale, density, and budget.

The presented guidelines help to build a safe environment for the people and natural ecosystems to thrive, despite the threats of the risks related to ocean change.

All of the design strategies aim at strengthening resilience. Some relate more to the construction of the building, others are related more to the function. Most of them implement each other.



The design is a programmatic illustration of a building following design strategies for resilient architecture. The location of the project is Mahé, however the specific context of the location has not been included in the design to make it more universal and easier to implement in other case studies or coastal communities around the world.

The design proposes a Blue Education Center that combines research and education functions with a space for collaborative interactions, with the main purpose of strengthening the coastal resilience.