Philosophiae Doctor (Ph.D.)
Thesis 2020 • 38

Multispecies Neighbourhoods in Urban Sea Areas

Multiartslige nabolag i urbane sjøområder

Elin Tanding Sørensen

NMBU

Multispecies Neighbourhoods in Urban Sea Areas

Multiartslige nabolag i urbane sjøområder

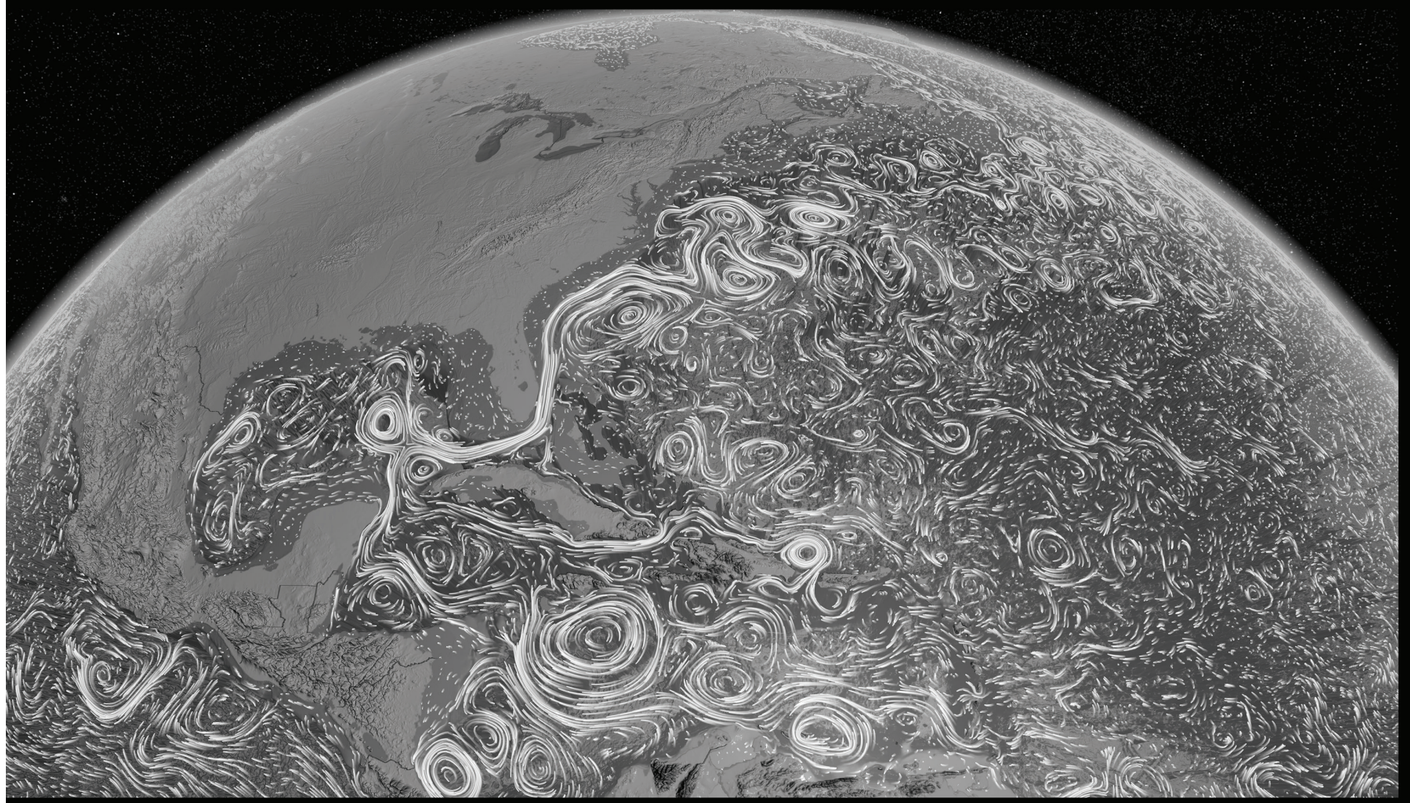
Philosophiae Doctor (Ph.D.) Thesis

Elin T. Sørensen

Norwegian University of Life Sciences
Faculty of Landscape and Society • School of Landscape Architecture
Ås September 2020

Imprint

Philosophiae Doctor Thesis
"Multispecies Neighbourhoods in Urban Sea Areas"
All rights reserved Elin T. Sørensen © 2020
Design by Elin T. Sørensen
Editing and proofreading by George Morgenstern
Printed digitally at CopyCat®
Set in Georgia, Corbel, and Avenir Next Condensed Medium
Book cover: Nautilus Classic 250 gram
Paper: Nautilus Classic 120 gram hundred percent recycled
Blue Angel, FSC™ recycled and EU Ecolabel certified
Format: A4 portrait 297 by 210 mm
Thesis language: English
Thesis number: 2020:38
ISBN: 978-82-575-1702-1
ISSN: 1894-6402
Edition: 15
Pages: 202





This thesis concerns the interface between landscape architecture, marine biology, art and urban development. It is motivated by a need to act and to help people discover a hitherto invisible landscape by creating awareness of its spatial qualities, colours, the smell of low tide and the myriad of lifeforms there. The aim is to expand the horizon of those building into this watery world. With a desire to create diverse and liveable urban bluescapes, the work has emerged in and through a state of wonder.

Opposite page, above: still from the video "Our Perpetual Ocean" showing the swirling flows of tens of thousands of ocean currents were captured in this scientific visualization created by NASA's Goddard Space Flight Center in Greenbelt. The animation covers the period June 2005 to December 2007 and is based on a synthesis of a numerical model with observational data. Below: micrograph of plankton ingesting tiny fluorescent polystyrene microplastic beads shot at Plymouth Marine Laboratory. Still from the short film "Ren Kyst – got a spare afternoon?" reprinted by permission from Bo Eide & Verity White/Five Films © 2013. Both videos were shown in the art installation "Kaurene" (The Gyres) by Elin T. Sørensen, Stein Sørensen and Erle Stenberg © BONO 2014.

The videos can be viewed at Research Catalogue
https://www.researchcatalogue.net/view/848167/962380

Abstract

The point of departure for this landscape architectural research is a seemingly forgotten and invisible landscape: the urban intertidal. The urban sea areas of the inner Oslofjord in Norway are explored through multisensory learning — driven by curiosity and wonder. For example, snorkelling has become indispensable to my investigative practice as a means of connecting with the tidalscape and marine life.

One problem addressed is how the ocean and its coastlines are increasingly densified and cluttered with human infrastructure. These intertidal interventions alter the physical, chemical and biological environment of marine ecosystems and, in the case of current building practices, deprive people of the opportunity for close, tactile contact with the sea. The hardened coastscapes of cities call for diversity, inclusiveness and shoreline softening. A key question in this thesis is how to improve coastal communities through urban development processes that take life below water into consideration: what does it take to get people to invest in an invisible world?

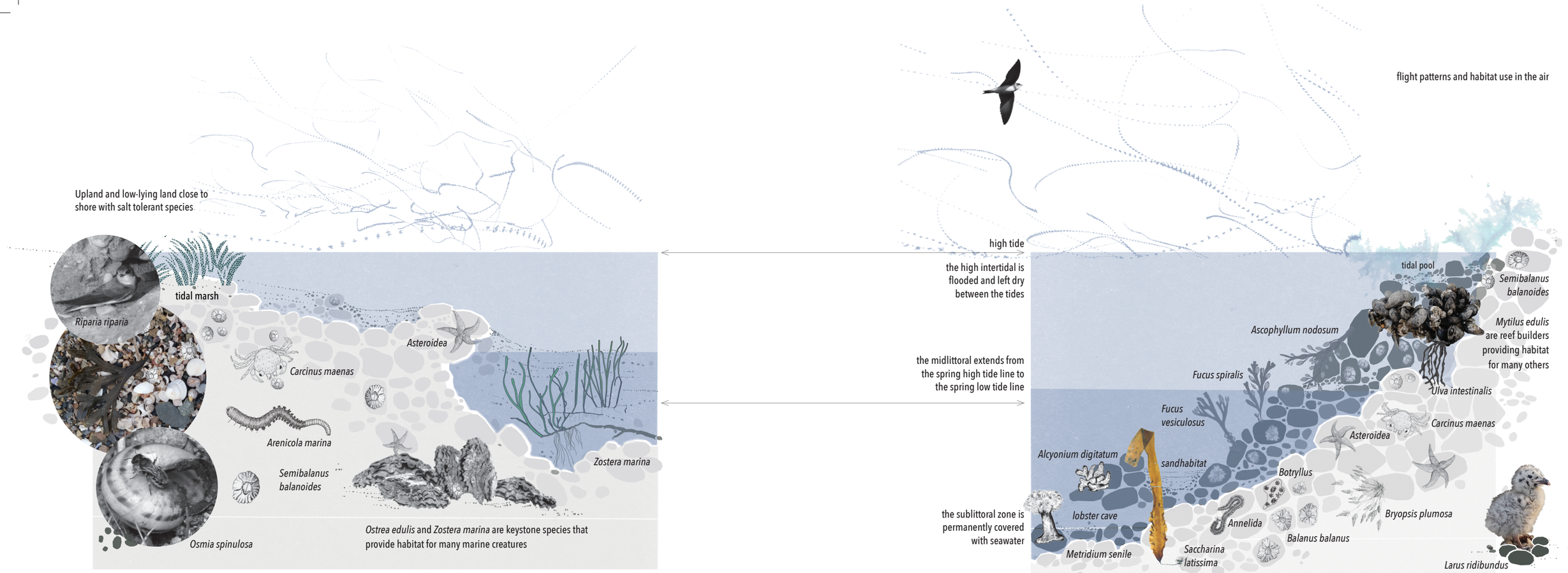
An attitude change is required. Emotion and empathy are essential components of such processes. This thesis builds upon the belief that art can work as a catalyst for change. Within eco-social art strategies, art practitioners try to broaden understanding through active and participatory co-creation, including ethical considerations about human-nonhuman relations. By *re/acting* with the ongoing developments of the Fjord City, this study builds on such exploratory action research. Given the aim of securing *multispecies neighbourhoods*, this thesis accordingly relies upon long-term engagements and deep co-creative practices. One way of achieving these conditions is by exploring the possibilities of *living laboratories*. Site-specific urban experiments, carried out in a one-to-one scale through the shifting seasons and yearly development, potentially provide the opportunity to learn from natural processes and users' interaction over time. Attempts to initiate living-labs as part of the Fjord City redevelopment sites have served as valuable learning cases.

The thesis argues that we must trust and recognize nature's capacity for self-design — and let nature-based solutions develop as freely as possible. Extending these ideas from the field of ecological engineering, a new branch of landscape architecture is articulated: *a marine landscape architecture* and *amphibious landscaping* which embrace nature's dynamics in inventive ways. A key question is how to transfer the complexity of nature onto the urban artificial shorelines. By means of digital fabrication, such as photogrammetry, 3-D modelling and additive manufacturing, concrete solutions for a local adaptive landscape architecture practice are explored.

Keywords: marine landscape architecture, multispecies neighbourhoods, practice-based research in the arts and architecture, co-creation and multisensory learning, digital fabrication, coastal eco-engineering, urban living laboratories

Contents

xi	Preface
xiii—xvi	Introduction
1—3	**Part I | Unveiling the invisible by forming a unified urban coastscape**
4—9	The Oslofjord
9—15	Coastal hardening of the inner Oslofjord
16—17	Wonders between land and sea
17—23	Multisensory learning through mapping and visualisation
24—33	Exploring a poetic language for landscape dynamics
35	**Part II | From marine deserts to multispecies neighbourhoods**
36—40	Re-naturing the urban intertidal
41—44	Applying rocky shore ecology to the 'real world'
45—57	The seashore and its inhabitants
57—66	In search for a marine landscape architecture
67—79	Digital fabrication as production method
80—81	**Part III | Towards multispecies co-creation**
83—91	Exploration and serendipity
91—92	Undisciplined collaboration
92—95	Co-creativity
97—99	**Reflective summary**
101—103	List of engagements 2017-2020
105—109	List of figures
111—119	References
121—180	Appendix I
181—200	Appendix II
201	Author's Biography



Soft bottom habitat: mudflats and sandflats from which the seawater withdraws at low tide, consisting mainly of fine grain sediments with some larger boulders.

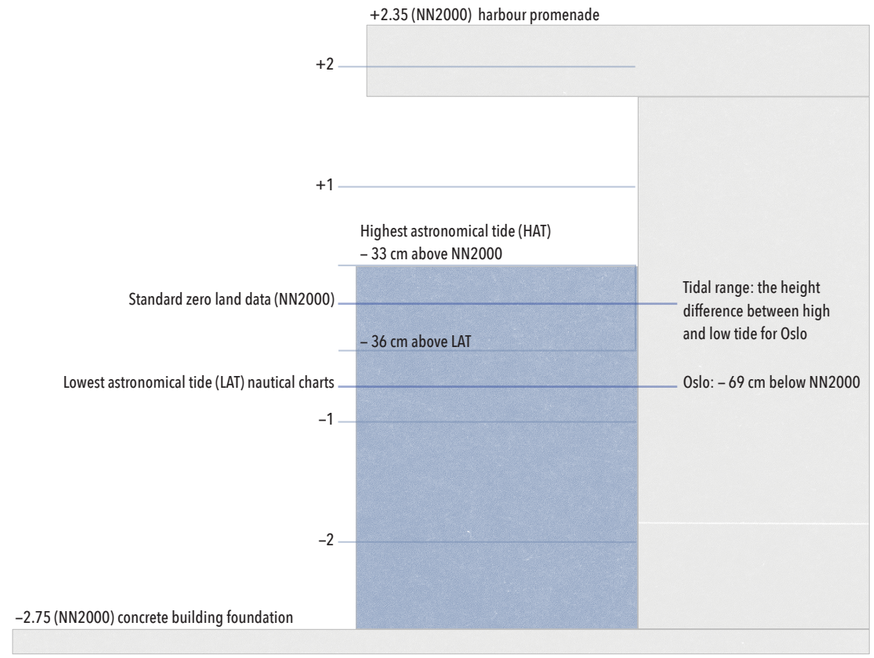
Hard bottom habitat: rocky shore, tide pools, steep rocky cliffs, reefs – and concrete hardscapes as below.

Tidalscape for beginners: an overview of the tidalscape and its vertical zones with examples of where you find different marine habitats such as eelgrass, rockweed and filtering animals along the shoreline. These examples are relevant for this thesis' study area in the inner Oslofjord.

The wet–dry cycle takes place along a *vertical emersion gradient* within which the rhythmic access to air and water is caused by the action of the tides and weather. The topography determines how species settle: a steep slope narrows the tidal zone and at the same time the effect of the waves are stronger. Oppositely, a gentle slope extends the tidal zone, and the as the wave moves into shallow water it slow down. The intertidal vertical axis has four physical divisions, each with ecological differences:

- The spray zone is the area above the spring high tide line that is regularly splashed, but not submerged by ocean water.
- In the high intertidal, the surface area is flooded during the peaks of daily high tides and left dry in the stretches between the tides. This is the home for stress tolerant species such as barnacles, snails, mussels and crabs.
- The midlittoral zone is the intertidal zone, known also as the shoreline, extending from the spring high tide line, which is rarely inundated, to the spring low tide line, which is rarely not inundated.
- The sublittoral starts immediately below the midlittoral and is permanently covered with seawater. The algal dominated zone, which may extend to fifteen meters below the low water mark in the inner Oslofjord, is called the infralittoral zone.

Diagrams by Elin T. Sørensen © BONO 2020.



The deepnosed pipefish (*Syngnathus typhle*) at Tofte

Eelgrass (*Zostera marina*)

DELL Ultrabook

A mail user agent

Marine biologists

Japanese wireweed (*Sargassum muticum*)

The Sørby beach at the Nesodden peninsula

Panasonic DMX-LX15 LUMIX

Geologist

The Internet

Hovedøya and its pocket beach with rock pools

A ruler and field magnifier

Sea lettuce (*Ulva intestinalis*) at Bleikøya

Acorn barnacles (*Semibalanus balanoides*)

The Norwegian Institute for Water Research

Pacific oyster (*Crassostrea gigas*)

Encrusting coralline algae (*Corallinales*)

Frognerstranda's seafloor desert

Canada geese (*Branta canadensis*)

Handy Recorder H4n

Notepad and drawing materials

Whooper swans (*Cygnus cygnus*)

Phragmites meadows (*Phragmites australis*)

Tube-building annelids (*Pomatoceros triqueter*)

The Norwegian Centre for Technology, Art and Music

Samsung Galaxy S7

Cambro-Silurian and granite geotopes

The urban demolition-waste rock fill at Kongshavn

Shipworm (*Teredinidae*)

The great cormorants (*Phalacrocorax carbo*)

Svestad shoreline and its shoals of little fish and blue forests

Shipworm (*Teredinidae*)

Freedivers

Sugar kelp (*Saccharina latissima*)

Maerl (*Corallinophycidae*)

Signal buoys

Lohavn and Sørenga

Starfish (*Asteroidea*)

A visionary urban developer

Blue mussels (*Mytilus edulis*)

Cambro-Silurian rocky shore

Concrete experts

Divers from Project Baseline Oslo

Heggholmen, blue forests and the flat oysters (*Ostrea edulis*) I never found

GoPro Hero Session

NIVA Research Facility at Solbergstrand, the hungry Green crabs (*Carcinus maenas*), Goldsinny wrasses (*Ctenolabrus rupestris*) and Bay barnacles (Balanus improvisus)

Project developers

Real estate owners

Bispevika

Ceramicists

Technical porcelain wreckage

Toothed wrack (*Fucus serratus*)

Common lobster (*Homarus gammarus*)

Black-headed gulls (*Chroicocephalus ridibundus*)

Bestumkilen

Moss animals (*Bryozoa*)

Microscope

The urban river estuaries of Hoffselva, Akerselva, Alnaelva and Bonnbekken

The eelgrass communities in Bonnebukta bay

An oceanographer

Filipstad

The Opera Beach

Bladderwrack (*Fucus vesiculosus*)

Underwater topography

CNC milling machine

NMBU Realtek Pilot Workshop

Oslo's historical landscapes and Port transformation designs from 1898 and 1915

A gypsum maker and the Cambro-Silurian sheepback

Landscape architect students

Håøya and the rainbow effect producing Comb jellies (*Ctenophora*)

Samsung Galaxy S6

Lysakerfjorden and the caseworker team at Bærum Municipality

Preface

This basis for this research originally stemmed from my passion for the invisible landscape of the sea and the question of how we can build environments that benefit our coexistence with living systems and the forces of nature. To change the current urban development practice of building into the sea, my desire has been to not only investigate, but to also develop tools and methods for multispecies neighbourhoods based on new collaborative approaches. In truth, I could not have achieved my current level of success without a strong support group and some of the co-creators are introduced on the opposite pages. The concern for the future of my son and his generation has also been a prime motivating factor behind my engagement in sustainable urban development of the urban blue and "ocean literacy," that is, our ability to read the ocean's influence on us and our influence on the sea.[1] My supervisor Dr. Anne Katrine Geelmuyden, Professor at The School of Landscape Architecture Norwegian University of Life Sciences NMBU has played a leading role in this project, and not least Co-supervisor Dr. Christian Blom, Director at Norwegian Centre for Technology, Art and Music. Lastly, I would like to acknowledge the support of marine ecologist Dr. Louise Firth for generously sharing insights and organizing the site visit to coastal-ecoengineering experiments in Plymouth. Thank you all for your unwavering support.

This work has been mentored by marine biologist Eli Rinde, geologist Johan Petter Nystuen and the visionary urban developer Anne Beate Hovind. Rinde is a senior researcher at Norwegian Institute for Water Research NIVA, with a doctorate in kelp forest ecology and extended experience in marine ecological studies. Many of the thesis' practical works are co-created with Eli Rinde. Nystuen is Professor Emeritus at the Department of Geosciences, the University of Oslo, with a long career as a dedicated teacher of biostratigraphy, sedimentology and palaeoenvironment. Within their respective fields, both Nystuen and Rinde are among Norway's foremost scientists. Hovind is a cultural entrepreneur whose practice is located in the interface of art, urban planning and business. She is renowned for producing ambitious long-term collaborative artworks and contributed to "Future Library" and "Losæter," both of which have received international attention and had a substantial effect on Oslo's waterfront. Our collaborative coastal community art project "Under/sea" has evolved during the course of this thesis. The many conversations with my mentors have been of tremendous value.

The use of state-of-the-art visualization and mapping techniques in this thesis was made possible by support from Ard Innovation, which is the Norwegian University of Life Sciences' catalyst for innovation. Ard Innovation promotes entrepreneurship by assisting students and employees with the commercialisation of research and of student-based ideas.[2] Thank you, Kaia Kjølbo Rød and Jorun Pedersen for believing in the project. The thesis' digital fabrication is funded by NMBU's Idea Development Fund and seed funding for "interdisciplinary collaboration for sustainability." The latter happened by joining forces in creating the project "Sjøplanter og fjærelandskap" with Professor Dr. Hilde-Gunn Opsahl Sorteberg, researching sustainable use of macro algae at the Faculty of Biosciences NMBU. Thank you Ivar Kjellmo for enthusiastically solving all our challenges with the 3-D works. The involvement with porcelain has been guided by the ceramic artists Torbjørn Kvasbø, Tulla Elieson, Eirik Gjedrem, Ann Beate Tempehlaug, and not least production manager Roger Thorvaldsen at Norwegian Technical Porcelain NTP, a manufacturer of ceramic and composite insulators based in Fredrikstad, Norway.

I must express my gratitude to the following for encouragement and generousness: Marine biologist Hartvig C. Christie for your enthusiasm and for providing access to NIVA Research Facility at Solbergstrand. Annike Flo (NOBA) and Dr. Ursula Münster (Oslo School of Environmental Humanities) for believing in the project and for your valuable advices along the way. Professor Kristin Bergaust (Oslo Metropolitan University) for being the driving force behind the project "Oslofjord Ecologies" and all the adventures it holds. Karen Winther (NMBU Learning Center) for supporting the thesis audio-visual works. Bjørnar Markussen for providing the BIM-model for the Bispevika project B6a. Thank you, my professional friend and deep friends for all our conversations and your backing having kept me afloat: William, Brita, Kira, Nina, Geir Harald and "Matter, Gesture and Soul," Dragos, Ulla and Venke.

Nesodden September 15

Elin T. Sø

1 (Intergovernmental Oceanographic Commission, 2020)
2 (Ard Innovation, 2020)

Periwinkles (*Littorina littorea*)

Canon SLR 650D

A bright pink thread

The tunnel in Sandvika and the engineering geologist

A catalyst for innovation and entrepreneurship

Oslo's urban sea areas and the caseworker team at the Agency of Urban Environment & Oslo Waterfront Planning Office

The sandworms (*Arenicola marina*) and their castles at Kvaløya

Creative technologists

Lobster hotels

Lenovo Think Pad

Sand martin (*Riparia riparia*)

Spined Mason Bee (*Osmia spinulosa*)

Knotted wrack (*Ascophyllum nodosum*)

Drøbak aquarium and the Shore crabs (*Carcinus maenas*), Hermit crabs (*Paguroidea*), the Eelpout (*Zoarcidae*), and Shorthorn sculpin (*Myoxocephalus scorpius*)

A video editor

Ormsund, Fjordtunet and Spearos Oslofjord, a club for freediving, snorkelling and spearfishing in the Oslofjord

Zbrush

Norwegian BioArt Arena NOBA

3-D printer

A ceramic kiln

... and my most influential guide and inspirator
the Oslofjord

Introduction

This thesis encircles a submerged world — the zone between land and sea — including the urbanised coastline, the intertidal, its seafloor and life below water. I started out by suggesting that this is a world concealed, invisible and even non-existing in our consciousness. Now, after a four-year journey, I can state that the urban intertidal is clearly unknown to most people.

"Multispecies Neighbourhoods in Urban Sea Areas" concerns the interface between landscape architecture, marine biology, art and urban development. The explorative action research is motivated by a need to act-and to raise awareness of a hitherto invisible landscape — its spatial qualities, colours, the smell of low tide and the myriad of lifeforms within this symbiosis of sea and shore. The aim is to expand the horizon of those building into this watery world. With a desire to co-create diverse and liveable urban bluescapes, the work has emerged in and through a state of wonder.[3]

This compilation thesis comprises various formats: the collection of articles including two written papers, the digital presentation of the immersive art installation "HAV," staged at the Norwegian Bio-Art Arena NOBA Vitenparken Campus Ås in 2020, and an interview in Part II. Among other expressions, the thesis' investigative work has resulted in animated maps that merge terrestrial and marine topography, sculptural surface replicas cast from local geotopes, videos revealing the findings from the underwater fieldwork, digital fabrication such as photogrammetry, 3-D visualization and 3-D printed porcelain tiles inspired by marine organisms.

Along today's developed waterfronts, humans have removed themselves from belonging to the sea. *Shoreline hardening* is a term expressing the division between the marine environment and a human-centred urbanisation. When we create our functional and rational harbour and housing areas, the effect is that the natural shore is hardened and straightened, and the qualities and ecological functions of the natural rocky shore are erased.

I have set out to unify the landscape between land and sea, both in people's imagination and by concrete designs for building into the sea in more inclusive ways. A key interest has been processes of transformation and making change. I asked myself what I needed to do in order to open the urban intertidal in people's consciousness and literally make space for marine life in humanmade environments. Altogether, the work develops from a curiosity towards the hidden realm below water, accompanied by the overarching question of how we can re-connect to the sea and include its creatures in our life. This project is much of a utopian quest in envisioning an ideal world of co-existence. Nevertheless, I have done everything in my power to put it to life. This has entailed entering this unknown world and becoming acquainted with local marine communities of the inner Oslofjord, as well as with the marine research community, where my enthusiastic interest was particularly welcomed among the researchers at the Norwegian Institute for Water Research (hereafter NIVA).

Yet, even a marine researcher may overlook the urban sea areas. As these ecosystems are profoundly disturbed, they tend to view this environment as a lost cause. Divers and marine biologists involved with the inner Oslofjord's urban sea areas liken the hardened shoreline and altered seafloor to a desert and describe it as a harsh and stressful habitat — a condition classified in European natural resource management terms as a highly modified and disturbed water body.[4] I have myself witnessed this wasteland through underwater fieldwork, which can be viewed at The Research Catalogue: https://www.researchcatalogue.net/view/848167/848207 . The twenty-one selected videos document different intertidal landscapes — from vital nature to desert land. These experiences have been central to the thesis development. More, in paper #3, Rinde and I address these issues by proposing a stepwise procedure for *an urban blue habitat framework* and *a toolkit for multispecies neighbourhoods*.

3 (Carson, 1998/1965)
4 (Miljødirektoratet, 2016)

Integrating a diversity of interests

In a very broad sense, the main problem underlying this research is a human centred worldview. Humans are caged within their needs, desires and the feeling of supremacy, equipped as they are with their different machines and tools, professional or scientific languages. Core human drives have led to an immense loss of diversity and extinction of nonhuman species.5 This has also led to a loss of freedom and of acceptance between humans themselves, exemplified by siloed mentalities.

As regards the urban intertidal, the production of knowledge clearly takes place in separate worlds.[6] My aim has been to bridge the knowledge gap that exists within the urban planning community, as well as between all the professionals working with either land or sea. Decision makers, politicians, caseworkers and urban developers, green management and caretakers are ignorant of urban bluescapes. Likewise, architects, landscape architects, gardeners and the building industry seem to be ocean illiterates. As an example, when engaging in the ocean and impacts of marine debris in the artwork "The Gyres" (2013-2014), I experienced an epiphany towards my own profession, and felt a deep sense of shame for being an uninformed landscape architect practitioner with respect to the marine environment. There is a weak and even missing link between land and sea in landscape architecture education and within education in general. Therefore, I had to gather skills and build what I ultimately decided had to be a multispecies team, which implied a need to go beyond traditional research strategies.

Artistic action research

I have entered the ongoing urban development processes and engaged in public outreach and interaction events. From start to finish, the thesis suggested ideas and methods that have been tested against the real world of planning and design. Hence, the working concepts and approaches have been refined by participating in public meetings, team meetings with public authorities and decision makers; by engaging with NGOs and grass root initiatives; by organizing beach-clean-up actions and more. In this way, the thesis presents a piece of action research which is explained as a way of gaining insights into and contributing to positive changes in the environment by engaging with places, communities and situations. By reflection-in-action through the phases of the work, the researcher eventually develops a personal theory, thereby arriving at instances of new knowledge together with an emergent community of learners.[7] The list of engagements can be found after the thesis "Reflective summary."

Professor in art didactics Venke Aure expands exploratory action research into the field of eco-social art strategies. With the term "responsive artfulness," Aure includes the fostering of fresh perspectives on eco-social challenges through critical artistic thinking and making, for instance by addressing social, economic and environmental concerns through art.[8] Over the recent decades, an increasing awareness of the connections between art and science has developed — taking the form of "art-science," art-based or artistic research. Regarding the field of qualitative research methodology, the artistic researcher typically replaces conventional criteria such as generalizability and reliability with less goal-oriented exploration and open enquiry as working modes. To Aure, this exemplifies a growing need to articulate methods that correspond to artistic interests and ways of working. She tracks eco-social art strategies back to an eco-ethical paradigm articulated by artist and art historian Suzi Gablik. Here, the art practitioners move from merely being observers of the state of our world to becoming active, participating co-creators. Gablik points to artistic efforts at reaching shared understanding by "intertwining of self and other, self and society." This also implies ethical considerations around human-nonhuman relations.[9] In another example which underpins the above perspectives, Aure draws upon Andrew Brown's analysis on ways in which contemporary artists are confronting nature, the environment, ecology and the climate crisis.[10] Regarding this study's exploratory action research, one of the six aspects of ecological commitment extracted from Brown's model is useful. His term *Re/act* refers to artists actively setting out to "transform the world and change it for the better."

5 (Díaz et al., 2019)
6 (Rinde & Sørensen, 2019)
7 (Mills, 2013; Stringer, 2004; Øgrim & Johannesen, 2014)
8 (Aure, 2020)
9 (Aure, 2020, pp. 149-150; Gablik, 1992, p. 6; Gablik, 2000, p. 26)
10 (Brown, 2014)

> No longer passive observers or reporters, or even engaged researchers, who leave the task of acting to others ... they seem more like eco-activists operating within an art context and using creative means to achieve their environmental goals."[11]

This thesis navigates between practical and design-driven research, artistic modes of operation and active dissemination of them. In order to unveil the undersea landscape, the work relies upon a strong urge to visualise my experiences. The study engages with writers and theorists — from poetic renderings of the world undersea to philosophical thoughts on nature and the nature of things. The establishment of effective teams and co-creativity are vital driving forces of this work. I have sought to be a humble researcher listening to the feedback and opinions of others. And the work as a whole relies upon long-term engagements and deep co-creative practices.

The urban blue

Ecologically sensitive approaches to urban designs are not new: Already Alberti (1404—1472), in the first modern treatise on the theory and practice of architecture, warned: "For so great is Nature's strength that, although ... some huge obstacle may obstruct her, or some barrier divert her, she will always overcome and destroy any opposition or impediment; and any stubbornness ... displayed against her, will eventually be overthrown and destroyed by her continual and persistent onslaught."[12] According to landscape architect Anne Whiston Spirn — who among others has articulated ecological urbanism as a framework for the design of resilient cities — Alberti underscored this warning by cataloguing the disasters suffered by cities that had disregarded the power of nature.[13] Looking at the long history of architecture and urban design, examples of integrated practices where marine interests stand in the forefront are few. So far, I think the tendency in Norway shows a foreshore transformation reflecting human interests only. Regarding the emergency of species extinction, I believe we have a responsibility to restore and repair the disturbed seafloor and shoreline to be habitable places — both for people and marine life.

An exploratory journey undersea

This exploratory journey can best be told as a travelogue, and from now on, I shall recount to you as well as I know, how I went about the work and how it became anchored to the wider research community. This thesis is not structured in a way that presents methods separately from the work's results. Rather, the methods employed will be presented together with the results as they occurred during the working process. The following summarising article is structured in three parts, reflecting my learning process and the way I myself have been transformed through this research. Each of these parts draws inspiration from the modes of being in the world which Hannah Arendt has described in her book "The Human Condition" from 1958.[14] In the mode of *Labour*, humans go about their daily life, experiencing the world physically and emotionally, with the foremost purpose of staying alive. Correspondingly, I introduce the reader to my experience of the urban intertidal as a landscape of the senses in the first part of this thesis. In Arendt's mode of *Work*, humans create durable objects such as tools, buildings or gardens, with the purpose of improving the conditions of human living. In the second part, I present my efforts to create tools and landscape architectural inventions that may be of use in transforming the urban intertidal to a more livable place for marine life and humans. Arendt describes the mode of *Action* as the activity humans engage in when they articulate and voice opinions and values in the social realm. Accordingly, the last part presents the way in which I have worked to influence various stakeholders and authorities involved in the planning of Oslo's waterfront. The landscape architects Anne Katrine Geelmuyden and Marius Fiskevold suggest Arendt's phenomenology of human practice as the basis for a nuanced and complete picture of what a landscape is. New insights within the field of landscape architecture can be gained through reflection on how these three modes of acting complement each other.

11 (Aure, 2020, p. 139; Brown, 2014, p. 218)
12 (Alberti, 1452/1988, pp. 35-36)
13 (Spirn, 2013)
14 (Arendt, 1958/1998)

In this way, a whole range of ethical issues concerning the interaction between humans and nature which should be dealt with in landscape planning are addressed.[15]

The extraordinary aspect of this research work is that it has already achieved change. Awareness concerning the urban intertidal has been raised, a new branch of landscape architecture is established. A couple of urban living laboratories for the development of multifunctional marine neighbourhoods are coming to life. The two NIVA and NMBU reports have been the start of articulating a common language for the urban intertidal, having trickled into the urban development processes in the Oslo region. One of the reports have even been included as a guideline to the architectural competition "Kanten" in Vejle municipality in Denmark.[16]

Like a catalyst, I have initiated a movement that lives on beyond this doctoral work. My hope is that the summary article can work as a guide in giving directions for ways of achieving a marine landscape architecture practice.

Part I | Unveiling the invisible by forming a unified urban coastscape

Part II | From marine deserts to multispecies neighbourhoods

Part III | Towards multispecies co-creation

NOTE

The thesis includes three articles. The first is a presentation of the mixed media installation "HAV," (2020) adapted as a digital art experience for the Research Catalogue: an international database for artistic research and a platform for the dissemination of self-published content and peer-reviewed publications – hereafter referred to as RC. **The artworks in "HAV," including video works like the undersea fieldwork**, is self-published, and by this, turned into a fixed state as part of the thesis' collection of articles.

Next, the essay "The Mussel's Voice,"[17] (2020) published in the anthology "Oslofjord Ecologies. Artistic Research on Environmental and Social Sustainability"[18] – hereafter called the mussel essay.

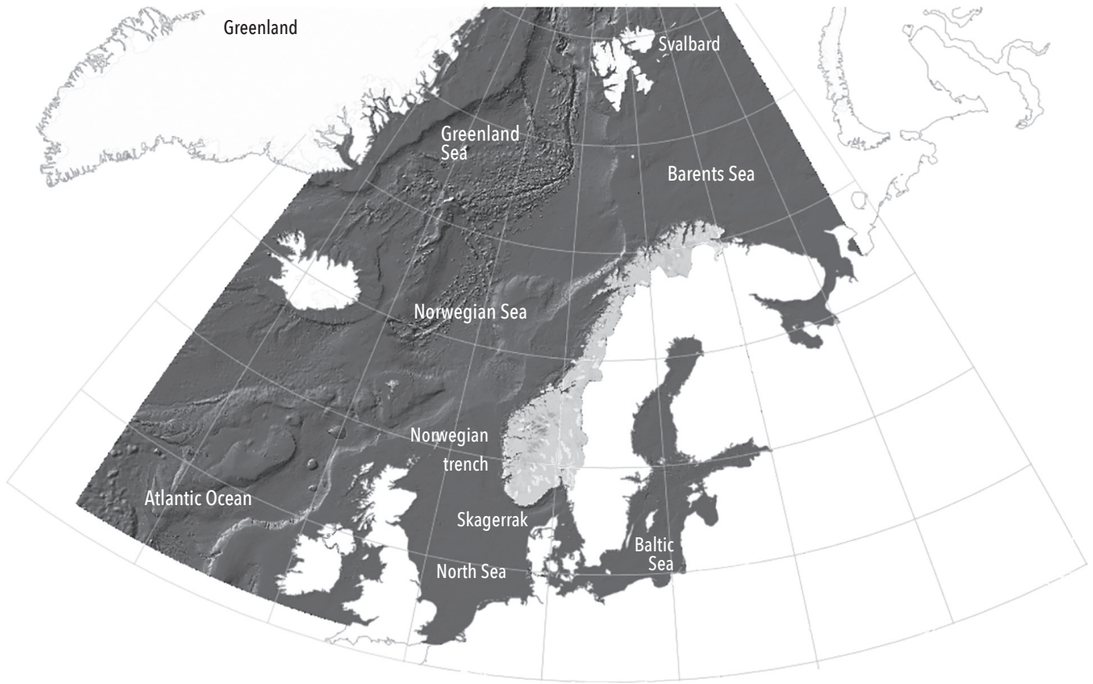
Last, the post-printed version of the paper "Enhancing marine biodiversity along urban shorelines: stepwise guidelines for an urban blue habitat framework, a marine neighbourhood toolkit and a common learning platform" (2020) – hereafter called paper #3. These works are included in Appendix I.

Appendix II contain extended information on the following: a short presentation of local marine nature types adapted to the Oslofjord. Short presentations on the thesis' living blue-lab initiatives. A summary of the two publicly available reports made together with NIVA on behalf of the coastal municipalities Bærum and Oslo – hereafter called the NIVA and NMBU reports. A short presentations on four practical examples of coastal eco-engineering at a landscape scale.

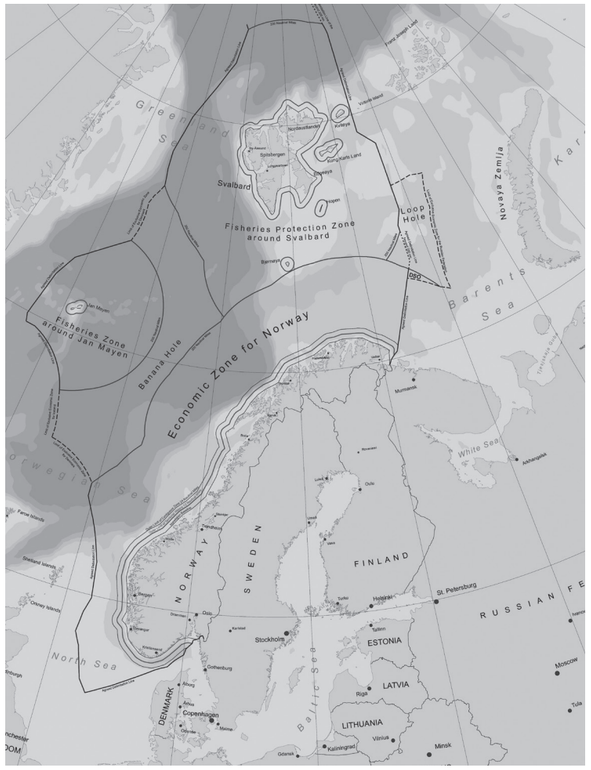
Throughout the thesis, samples of the practical and visual work are presented.

15 (Fiskevold & Geelmuyden, 2018)
16 (Rinde, Sørensen & Haraldsen 2019; Rinde & Sørensen et al., 2019; Tiselius, 2020)
17 (Sørensen, 2020)
18 (Bergaust et al., 2020)

Part I
Unveiling the invisible by forming a unified urban coastscape



Shaded relief map of Norwegian waters by MAREANO 2008, retrieved July 2020.



Norwegian Maritime Boundaries, map by The Norwegian Military Geographic Service Oslo, September 2012, retrieved July 2020.

https://www.regjeringen.no/contentassets/1490c8d4b-f9843ecb22970bdcde39d6c/20121002_fmgt_overview_norge_nor-domraadene_norske_maritime_grenser_7.5m_h61xw52_p_jb_ed04_ugradert_300dpi.pdf

Unveiling the invisible by forming a unified urban coastscape

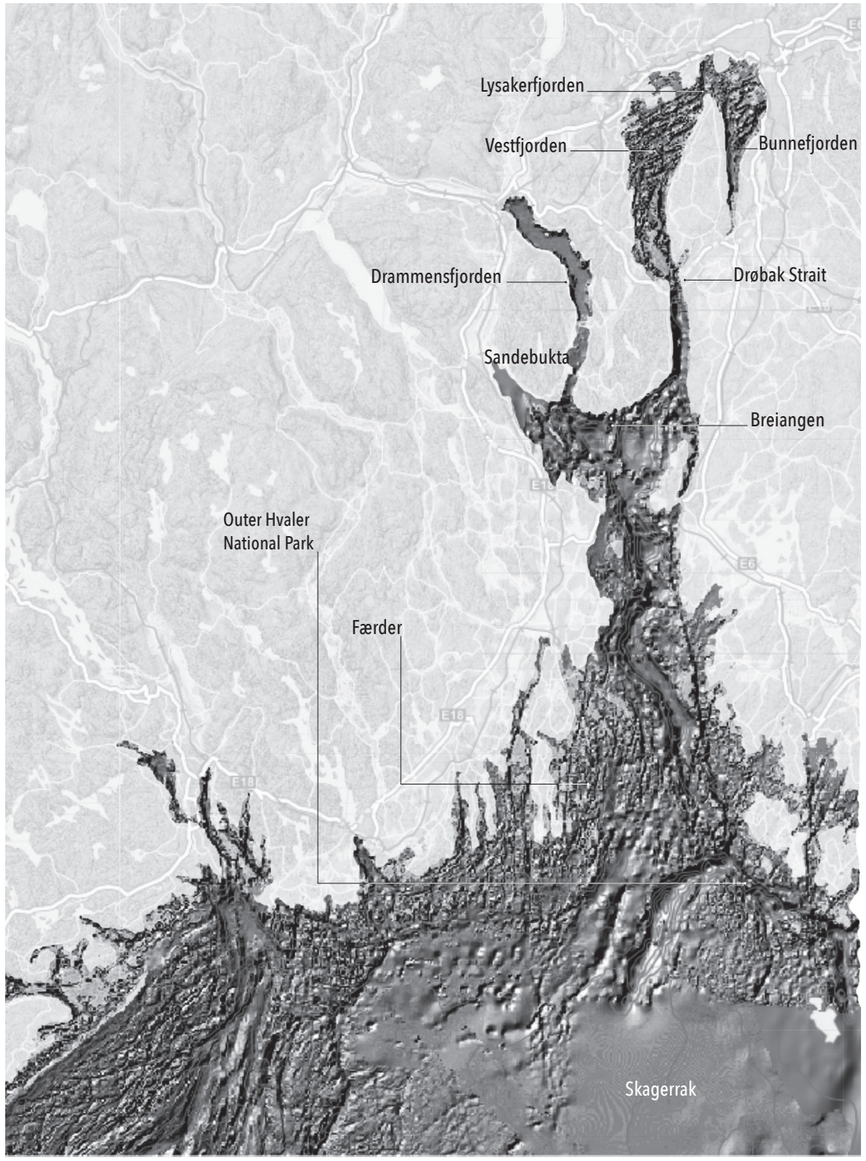
I have set out on a quest in search of a unified vision of land and sea, to show it as a landscape in its own right which needs to be taken into consideration during urban planning and development. The thesis' sensory field-work is driven by an aim to unveil the urban sea areas and gather information that could help me to actualize this landscape in people's consciousness. Therefore, I had to get to know this landscape myself through direct experience and engagement with it. This has laid the foundation for developing new methods and making architectural interventions that truly account for life below water. These attempts are described in part II of this study. The following sequence, however, is dedicated to this thesis' lead actor — the inner Oslofjord. This body of water is the deep structure that has supported the coastal communities which have settled along its shore. The fjord is also the foundation for the life of marine creatures. However, humanmade infrastructure has hardened a good portion of the coastline. In fact, the entire fjord is marked by the consequences of human activities. Its water is becoming darker and life below water struggles. Marine researchers tell us that the Oslofjord is "sick, and something needs to be done."[19]

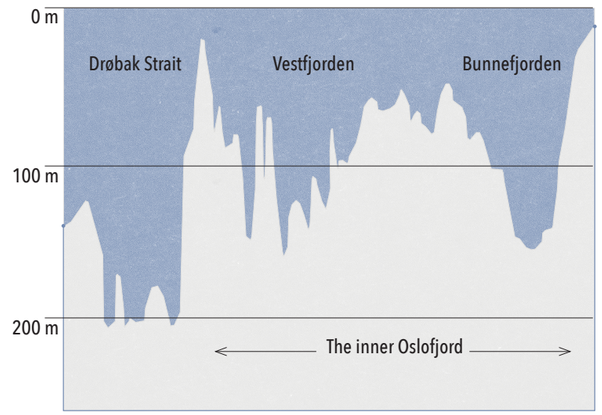
Life below water

Once the fjord held an abundance of cod, lyre, whiting, herring, sprat, seals, Porpoise and seabirds living off the richness of its waters. Today the fjord is almost empty of fish. All cod species of inner Skagerrak are reduced by as much as 86 percent over the last hundred years. In the 1950s, kelp forests, such as sugar kelp, could thrive down to 25 meters' depths in the outer Oslofjord. Today, the sunlight only reaches down to about 14 meters. Its inner part lacks oxygen, and life forms below water struggle.[20] Cod fishing is now prohibited throughout the year in the Oslofjord.[21]

In the following, I share my experiences from immersing myself in the wonders between land and sea. I have walked, climbed, waded, swum, and snorkelled in order to gain new insights on the coastscape through the impressions of my senses and emotions. In studying a place, I claim "the sense of wonder"[22] is an essential tool for landscape architects. Hence, new knowledge has evolved by means of multisensory learning, through mapping and landscape visualisation. In order to portray the living dynamics of this landscape, a poetic language is explored using various methods and techniques such as time-based media and animation. A key interest has been grasping intangible qualities, as the transitory moods of the light phases. I have also tried to depict dramatic changes in landscapes such as the scale of predicted flooding, the fluvial process of a river, and the gradual coastal hardening of Oslo's waterfront exemplified by, among other things, the demolition of one of the islands off the city coastline. These experiments can be viewed at RC: https://www.researchcatalogue.net/view/848167/880094 . The making of these landscape visualisations has been one way of seeing and comprehending the properties of the tidalscape, which at the start of this explorative journey was unknown to me. What is at stake is a new outlook on the urban intertidal, perceiving this realm as a unified whole with its own relational life-dynamics. Some results from these expeditions are visualized in the art installation "HAV," staged at Norwegian BioArt Arena at Vitenparken Campus Ås from February 27 to December 2020 and adapted for a digital dissemination at RC: https://www.researchcatalogue.net/view/869494/869495 .

19 (Moland & Knutsen, 2018; Translated by Elin T. Sørensen)
20 (Moland & Knutsen, 2018; Translated by Elin T. Sørensen)
21 (The Norwegian Directorate of Fisheries, 2019)
22 (Carson, 1998/1965)





The Oslofjord

The Oslofjord is a body of water which looks like a swan from a bird's eye view. Its "body" is Breiangen, its lifted "wing" Drammensfjorden, the "tail" Sandebukta. Its long "neck" is formed by the Drøbak Strait with Bunnefjorden forming its head and beak. After flowing through the strait, the main fjord opens into several side fjords: Vestfjorden, Lysakerfjorden and Bunnefjorden. Its water flows in and out through the Skagerrak, the strait between the southeast coast of Norway, the southwest coast of Sweden, and the Jutland peninsula of Denmark. In turn, these waters are renewed by circulation from the Atlantic Ocean , which again is closely linked to the world oceans and the seas encircling the North and South Pole.

From Færder in the outer Oslofjord to the innermost bay in the side fjord Bunnefjorden, the fjord is about 120 kilometres in length. The marine landscape of the inner Oslofjord varies greatly, its depth ranging from shallow waters down to 164 meters. Its many isles and skerries divide the landscape into several basins, amongst them the Bærum and Bekkelaget basins near the urban foreshore. The inner Oslofjord holds about forty islands and skerries, and along its shore, seven urban rivers flow into the fjord. The largest rivers are Sandvikselva, Lysakerelva in the west, Akerselva in the city centre, Alna, Ljanselva, Gjersjøelva and Årungselva in the east.[23]

The blue treasure chest

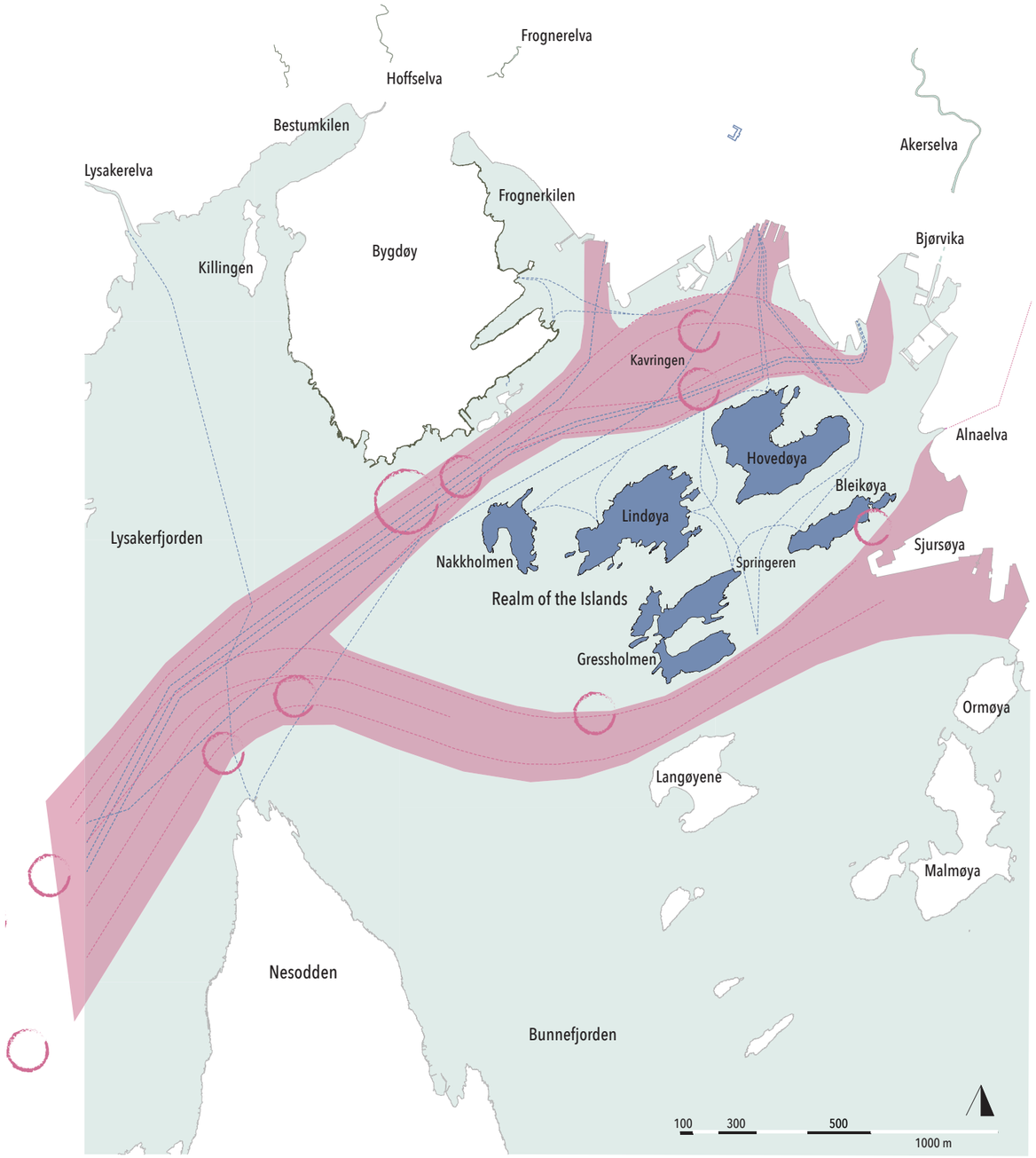
In the late 1800s, one could observe a man in a small rowboat on the inner Oslofjord. This was the marine biologist Georg Ossian Sars (1837-1927). Sars collected marine material which he meticulously drew and described, documenting some species that still live and others that are gone. As a curiosity, Michael Sars (1805-1869) — one of Norway's most prominent zoologists in his time — discovered corals in the Drøbak Strait in 1865. From 1900 and onward, the Oslofjord has been the subject of scientific research within branches such as marine biology, sedimentology and geology, and hence, is claimed to be one of the world's most examined fjords and harbour areas.[24] The ocean is full of treasures. The Norwegian Government regards the country as a leading ocean nation. Norway has one of the world's largest oil and gas productions; it has an advanced shipping industry and is the world's second largest exporter of fish and seafood. Norway is considered as being at the forefront of ocean research and responsible marine resource management. Nevertheless, detailed knowledge of the marine environment is poor, and the Norwegian Environmental Agency lacks insight into many nature types along the Norwegian coasts.[25]

Thresholds and water exchange

The oceanographer Andrè Staalstrøm at NIVA describes Oslo's inner harbour basin is defined by a threshold depth of 22 m, its area being located between the islands Nakkholmen, Lindøya and Hovedøya. Due to the decomposition of organic matter combined with the low exchange of water near the bottom, the oxygen level of the basin was found to be very poor in the period 2015-2018. It was uninhabitable for fish or shrimp. Without marine life, nutrients accumulate in the water. This, together with surface runoff, makes the water "dark," that is, limits light penetration.[26]

Opposite page, above: Shaded relief map of the Oslofjord by MAREANO 2008, retrieved July 2020.
Below: Schematic cross-section of the inner Oslofjord. In the section Bunnefjorden is aligned with Lysakerfjorden and Vestfjorden. The Drøbak Strait, about 30 km south of Oslo, has a threshold with a maximum depth of approximately 200 m. Vestfjorden's maximum depth is 164 m and Bunnefjorden's is 154 m. The vertical scale is exaggerated in relation to the horizontal scale. Diagram by Elin T. Sørensen © BONO 2020, based on Baalsrud & Magnusson 2002, p. 18 (fig. 3).

23 (Baalsrud & Magnusson, 2002, pp.15-19, 23; Thorsnæs, 2020; Both translated by Elin T. Sørensen)
24 (Baalsrud & Magnusson, 2002, p. 75; Translated by Sørensen)
25 (Government.no, 2018; Norwegian Environment Agency, 2018)
26 (Rinde & Sørensen et al., 2019, p. 15-17)

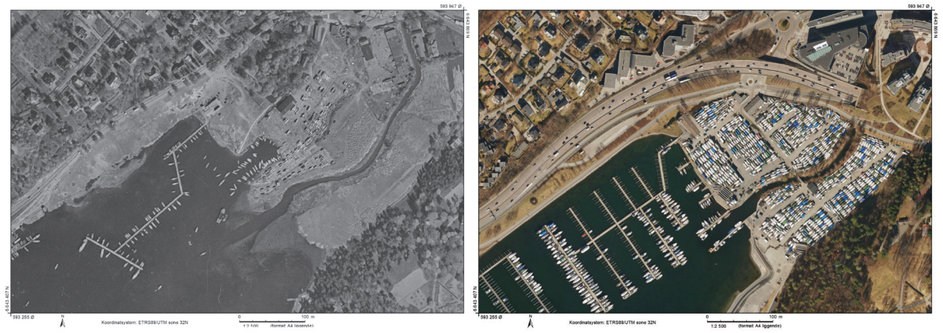


The inner Oslofjord's blue highway. The red circles show the excavated grounds facilitating the traffic lanes. The red dotted lines show the sea-lanes for the larger tourist and cargo ships and the blue dotted lines show the lanes for the local ferries. Oslo's inner harbour basin is defined by a threshold depth of 22 m, its area being located between the islands Nakkholmen, Lindøya and Hovedøya. The deepest areas undersea extend from north of Nakkholmen to Kavringen. South of Kavringen there are areas with depths down to 29 m. There are equally deep areas by Springeren. The City of Oslo have envisioned and defined the central islands as the "Realm of the Islands" for recreation and outdoor activities. Diagram by Elin T. Sørensen © BONO 2020, based on Norconsult 2015 p. 10 (fig. 1), and the City of Oslo 2020 "Aktiv vannflate" (An Active Water Surface), pp. 10, 30.

A blue highway

The Oslofjord is Norway's most densely populated blue recreation area and has the busiest traffic of charter and leisure boats, ferries, and cargo ships. To meet these needs, the Coastal Administration has facilitated a blue highway through the inner Oslofjord. To make way for larger ships for the sake of safety, shallow banks and underwater reefs are removed by crushing and dredging the seabed. The project "Innseiling Oslo" (Sailing to Oslo) completed its dredging in the spring of 2016, whereby 24 shallow banks and reefs were eradicated between Drøbak and the inner harbour basin, deepening the landscape below the traffic lanes from 11 to 14 meters. These new sea-lanes interfere with spawning areas for Cod. The disposal of excavated masses as well as shockwaves and noise-pollution from the underwater explosions had a significant impact on marine life.[27] The Norwegian Environmental Agency did not choose to penalize the Coastal Administration; however, the police issued a fine of NOK 200.000.[28] The project caused substantial debate within the coastal community.

The modern sedimentation regime in the inner harbour basin is strongly influenced by the aforementioned traffic. Within the navigation paths of cruise ships and large ferries, turbulence generated by the propeller wash limits sedimentation. Locally this causes erosion of the seabed. The propeller-induced erosion affects the marine environment negatively by exposing and remobilizing sediments from previous decades that are severely contaminated.[29] What is more, the inner Oslofjord is increasingly used as a blue parking area. Bestumkilen is an example of *ocean sprawl*, as leisure boats, pontoons and marinas cover almost the entire bay.[30]

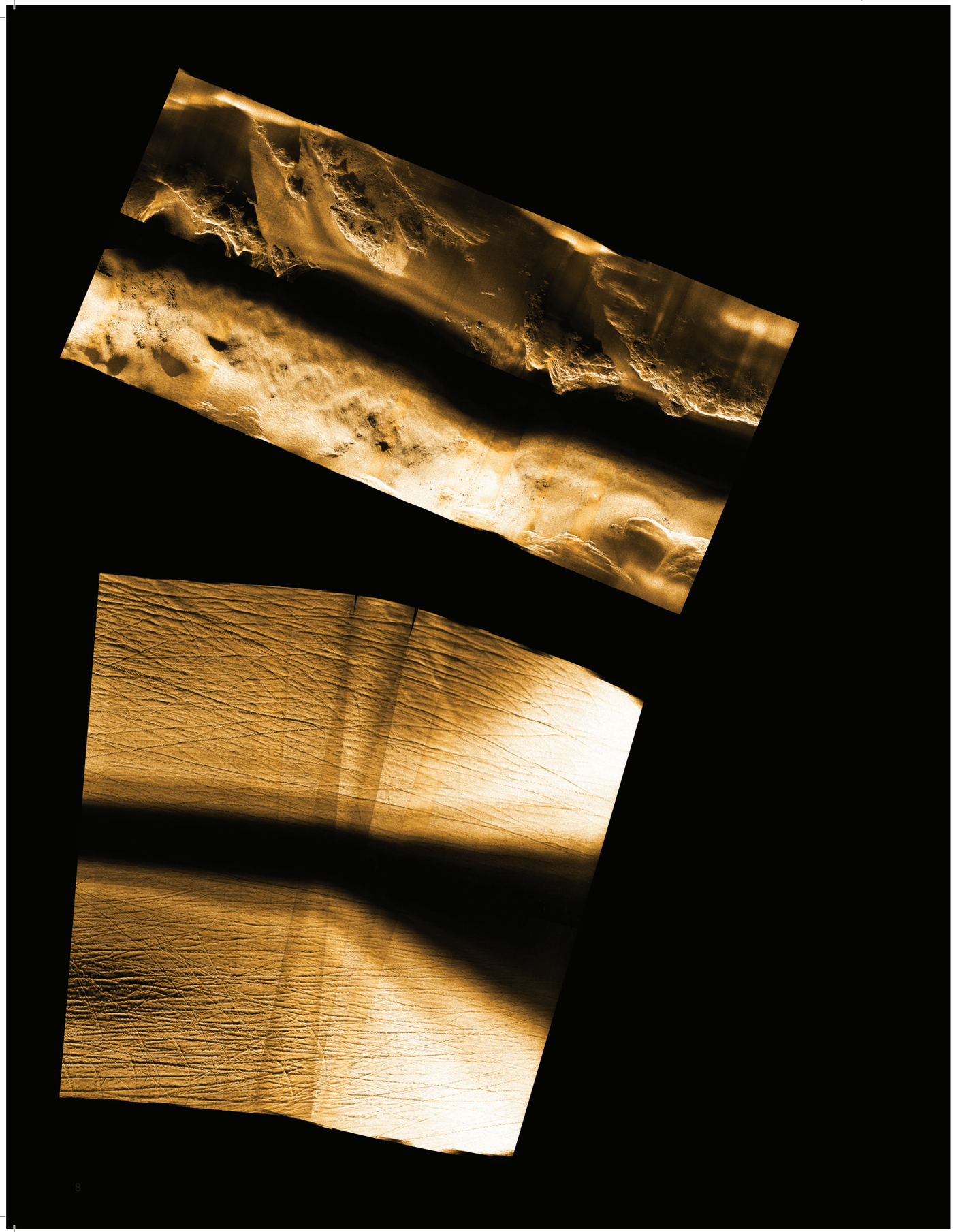


Bestumkilen in July 1956 and May 2019, showing the increased use of the bay as well as Hoffselva's floodplain and estuary as a parking space for boats. Maps retrieved from norgeibilder.no, August 2019.

Clean up of the inner Harbour basin

Between 2006-2011, a major environmental effort was implemented with the project "Ren Oslofjord" (A Clean Oslofjord), during which about 450.000 m² of polluted masses from the development areas in Pipervika and Bjørvika were removed to improve water quality. The contaminated sediment was dredged and transported to the deep-water landfill at Malmøykvalen, where the masses were brought down to the seabed via a closed pipe. These actions caused considerable disagreement and debate among people and stakeholders of the fjord. Yet the seafloor hasn't stayed clean. Surveys show that the areas of the clean up are gradually being polluted again due to surface runoff. The contaminants observed on land are found to accumulate in the sediment of the urban intertidal. This is a clear sign of the city's continual polluting of the fjord.[31]

27 (Norconsult, 2015; The Norwegian Coastal Administration, 2015)
28 (Løken & Jenssen, 2016)
29 (Lepland et al., 2010, p. 1522)
30 (Rinde & Sørensen et al., 2019)
31 (Oslo Havn, 2013, p. 10; Translated by Sørensen)



Scars on the seafloor

The objective of “Frisk Oslofjord” (A Healthy Oslofjord) is to gather knowledge to form the basis for a sustainable management of the fjord’s marine resources and environment. A main focus is investigating the seafloor, both in shallow and deep water, using state-of-the-art mapping methods. Among these is the autonomous underwater vehicle “HUGIN,” a robot that travels underwater without requiring input from an operator, developed by the Norwegian Defence Research Establishment (FFI) and Kongsberg Maritime.[32] I discovered some of the project research finds through an invitation from Arne Johan H. Hestnes, senior software architect at Kongsberg Maritime. He took me on a journey down along the “great plains” of the outer Oslofjord, as far out as Tisler reef, which is known as the world’s largest inshore cold-water coral reef. Here the landscape is dramatic: depths vary from 29 to 462 meters and cliff walls are up to 60° steep. Altogether they house a rich marine biodiversity, containing species thriving in shallow water to deep living creatures. Luckily, much of the area is protected since it has been designated Norway’s first marine national park, Ytre Hvaler National Park. Despite this, these deep plains are marked by humans. An undersea exploration reveals extensive trawling tracks from fishing activities — visible like scars on the seafloor, the trawlers having scraped the bottom down until larger geological features have stopped them. A couple of views from “HUGIN” are shown in the figures on the opposite page.

Coastal hardening of the inner Oslofjord

The sea washes the coastline, moving back and forth against a gently sloping beach or rocky shore — against a landfill or concrete seawall. The armouring of the shore to accommodate human needs is called *coastal hardening*. This gradual and increasing trend of replacing natural coastlines with artificial structures is also referred to as concrete-based coastal and marine infrastructure (CMI).[33] These concrete dominated hardscapes, celebrated as technological achievements, greatly differ from the marine creatures’ natural habitats.

A central question, for my part, is what we may achieve by reversing this trend to reclaim and repair the urban intertidal, restoring the landscape’s inherent structure and function.

The landscape’s deep structure

Anne Whiston Spirn, professor of landscape architecture and planning at MIT, characterizes the cityscape’s underlying enduring framework as a “record of the interaction between natural processes and human purpose over time.”[34] The urban tissue is in flux, evolving in continual response to the rhythms of its underlying structure and influenced by recurring climatic events and the geomorphic and biotic cycles at play. These sometimes unfold extremely slowly and at other times in shockingly abrupt ways across time and space and at different scales — from a regional to a microcosmic level.

Spirn sees urban design as a tool for human adaptation and urges planners, architects, and building contractors to treat cities as habitats and ecosystems that are dynamically interconnected to the land’s deep and enduring environmental context. Limiting or redirecting rivers’ water flow with narrow, straight culverts or covering floodplains are examples of non-adaptation to the environmental context. By responding to the landscape’s deep structure, the design of the urban environment, on the contrary, can achieve a form that is more functional, more economical, and more resilient.[35]

Opposite page: Undersea mapping showing the more pristine areas by the Tisler cold-water coral reef: the largest known coral reef in sheltered waters in Europe, within the Hvaler archipelago in the Outer Hvaler National Park. Below: Heavily trawled area shown as scars on the marine plains close to the reef. Underwater recording from 2019, published by permission from Kongsberg Maritime, Sensors & Robotics partner in “Frisk Oslofjord.”

32 (Frisk Oslofjord, 2020; Translated by Sørensen; Norwegian Defence Research Establishment, 2020)
33 (Perkol-Finkel & Sella, 2015, p. 260)
34 (Spirn, 1993, p. 17)
35 (Spirn, 2013)





Two examples of the proposals from the international competition addressing new harbour designs for the Port in 1897, No. 4 "Havneby af Rang" (Seaport of High Rank, unknown author), and No.5 "Nyt Land" (New Land, unknown author) which shows a channel between the bays Bestum- and Frognerkilen. Photocopied maps published by permission from the Port Authority of Oslo.

In much the same line, professor of geology and environmental studies, Dr. Marcia Bjornerud, has introduced the term "timefullness" — a concept she claims to be vital given the current state of accelerating planetary change a need for a more time-literate society. In order to make decisions based on multigenerational timescales, Bjornerud encourages us to think about place development in relation to time.[36]

The Oslofjord enters deep into the country, affording sea transport of goods from rich forests and agricultural areas. These conditions were favourable to the first human settlements and, henceforth, to gradual urbanization with the development of Bjørvika and Bispevika as Oslo's strategic transportation hub. As a significant zone of exchange between foreign input and the hinterland, Norway's capital Oslo has been a central port city since the Middle Ages. A century back, sea lanes were established for large shipping vessels to reach the "other side of the world," positioning Norway as a leading global shipping nation through the likes of the African-Australian Line, the Norwegian American Line, the East African and South America Lines, and the Pacific Line through the Panama Canal.[37] Nevertheless, Oslo's foreshore has been subject to a rather unclear design strategy.[38] During the thirteen years from 1898 to 1911, the central shoreline was completely transformed by "trading-off of landscape qualities, cultural history and aesthetics for the sake of rationality and logistics."[39] Numerous blasting and landfill operations straightened the shore. Old buildings were demolished, and new quays built. Constant renewal eventually resulted in a continuous industrial ribbon along the central seaside. The city's foreshore became a hard landscape, reflecting some of the incoming proposals from Norway's first international competition addressing new harbour designs, launched in 1897. Nearly 30 years later, in 1914, the Port Authority organized the next competition for the expansion of the port of Kristiania (renamed Oslo in 1924).[40] These new proposals are highly visionary and inspirational in their expressions of creative power and ambition to transform the landscape. These historical plans, descriptions and subsequent landscape interventions, including redirected watercourses and shoreline landfills, reflect the visions of a bygone era, the consequences of which can be illustrated by the following anecdotes.

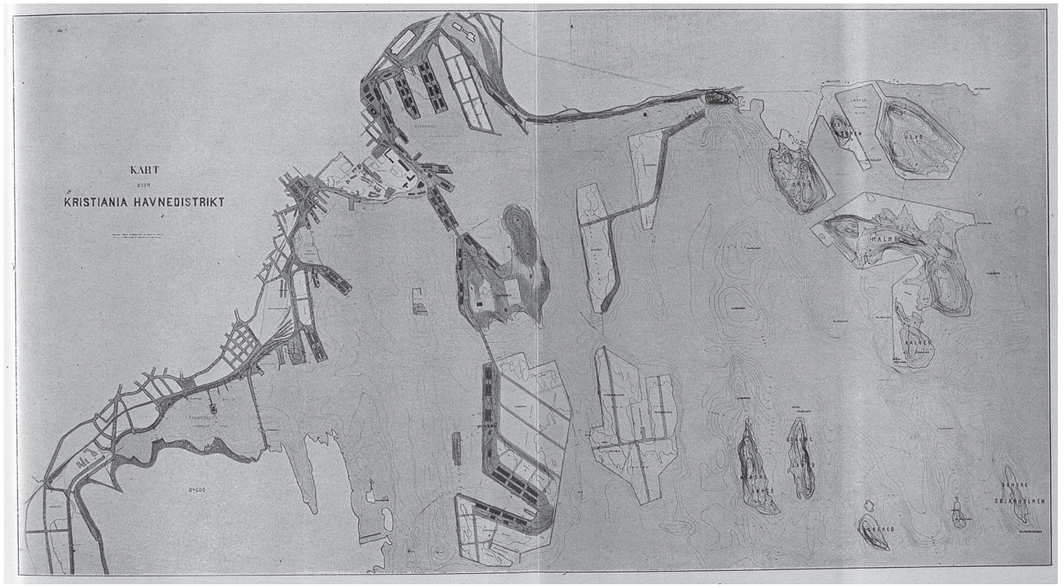
A thorn in the flesh

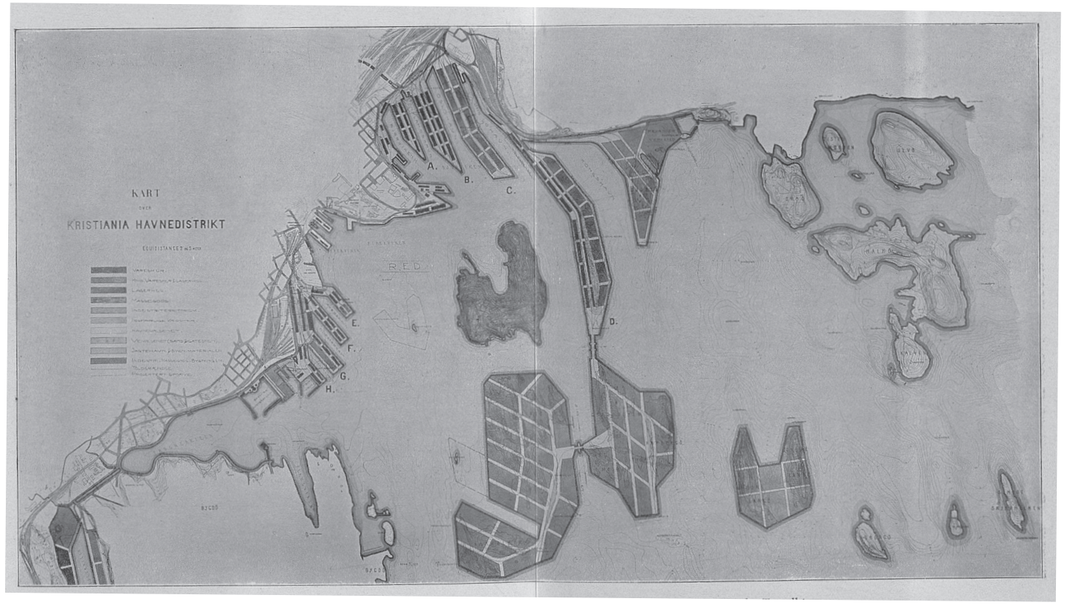
In 1917, it was decided to redirect the downstream part of the Lo River (Alna) through what became the two kilometre-long "Lo-tunnel." The river was channelled into a culvert by the foot of the steep hill Ekebergåsen to the fjord at Kongshavn. A news feature in a leading newspaper of the time shows that the operation was considered of great value to people's health and urban regeneration. To the Norwegian State Railways, which was keen to develop the river's floodplain, the waterbody had long been a "thorn in the flesh." Moreover, it was deemed of "great sanitary significance that the Lo River with its dirty raw sewage water disappears from earth's surface."[41] Alna's "estuary" was thus deprived from functioning dynamically. Flowing from a hole in a mountain into the fjord, the river has lost all opportunities to perform as a healthy lifeline for the city. The transitional space that could allow the river-system to freely and continuously change its water course-and sediment formations was lost.[42]

Paradise lost – Sjursøya

Five years before, in 1912, a 10-year old boy returns his brother's friends from a party at his family's summer house on the isle Sjursøya. The child was Johan Borgen (1902–1979), later to become a renowned author, journalist and critic. In his novel "Barndommens rike" (A Childhood Kingdom), he recalls his memory of rowing to the city centre with "the isles fairy-tale-like kingdom before my eyes."[43] Borgen portrays the short trip he and his family took every spring on the ferry "Tor" to spend the summer on Sjursøya. He writes evocatively about the summer residence surrounded by a mix of fruit gardens and wildlife which sets his imagination in motion. To the little boy, Sjursøya was the "garden of paradise."

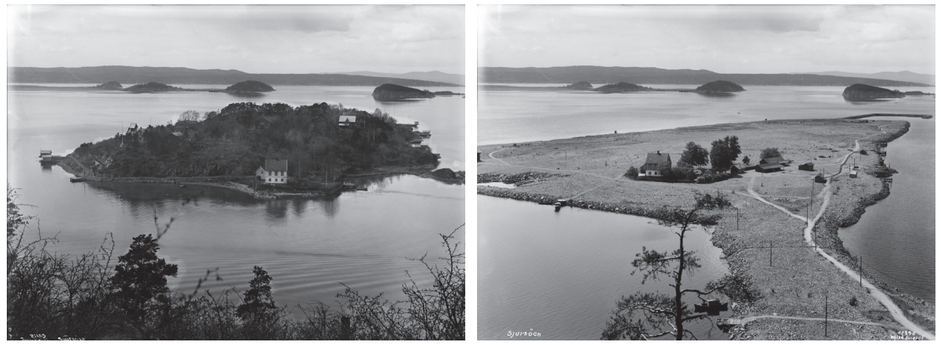
36 (Bjornerud, 2018)
37 (Oslo kommune Byantikvaren, 2008, p. 19; Translated by Elin T. Sørensen)
38 (Oslo Havn, 2011, pp. 13, 34; Translated by Sørensen)
39 (Oslo Havn, 2011, p. 36; Translated by Sørensen)
40 (The Port Authority of Kristiania, 1898; The Port Authority of Kristiania, 1916; Translated by Sørensen)
41 (Aftenposten, 1922; Translated by Sørensen)
42 (Nystuen & Sørensen, professional dialogues 2017-2020)
43 (Borgen, 1966, p. 106; Translated by Sørensen)





Two examples of the proposals for the competition in 1915, No. 8 "Ekonomi" (Economy), 1. purchase contribution by the author Chief Engineer Georg Møen, Kristiania Port Authorities, and No. 9 "Hovedøen," 3. purchase contribution by the authors Engineer B. I. Corwin and Engineer I. Lunde from Trondheim. Photocopied maps published by permission from the Port Authority of Oslo.

From his contemporary perspective as an adult, however, he writes: "the isle that has been transformed by modern progress, the isle that is demolished, blasted to pieces, and remodelled to a concrete peninsula, is today far from paradise."[44] As a sign of the time, the pulverisation of Sjursøya was, in fact, part of the capital's development towards a sustainable future. As the above figures show, the proposals from the harbour competitions envision the most futuristic styles: bridges connect the islands with the mainland and are given new "modernistic" and "cubistic" shapes. Due to economic downturns, most of these prospects never left the drafting table. Sjursøya remains one of the few visible results of the visions from the beginning of the twentieth century.[45] This is because Oslo municipality bought the island in 1920, expropriated the land, tore down the country houses and even the land itself. The process also created jobs for the unemployed. From 1921 to 1934, 1.500 men worked around the clock and 90.000 m3 rock aggregate was relocated within the harbour basin. The rock material from Sjursøya was among other reused in the landfill that today forms the embankments of the redirected Alna River's marine estuary mouth. Now this island, or concrete peninsula, stands as an industrial heritage site, with gigantic harbour cranes and expressive industrial architecture serving as distinct landmarks in the inner Oslofjord.[46]



Sjursøya 1919/1935. Flip animation by Elin T. Sørensen © BONO 2018 based on original photos by Anders Beer Wilse 1919/1935 published by permission from Oslo Museum. The animation can be viewed at RC: https://www.researchcatalogue.net/view/848167/880105

The Fjord City

Today, the Fjord City, Norway's most ambitious waterfront renewal project and the most comprehensive urban transformation in the country's history — considered one of the largest developments even in Europe — is taking shape. In the year 2000, the city council of Oslo approved a "Fjord City Strategy," a roadmap for remaking the port city into a Fjord City with an expected completion by 2030.[47] Intended to meet a growing population, from 685.000 in 2018 to 833.000 by 2040, the Fjord City has at its disposal 2.261 acres of floorspace for the establishment of about 9.000 new homes and 45.000 workplaces.[48] Its Harbour Promenade and the seven public "Commons" make up the foremost ingenious planning decisions, together securing the area's share of open social spaces. With its average width of 20 meters, the Harbour Promenade accommodates a generous public space connecting east and west.

This hard cityscape represents a new urban deep structure. As such however, it limits rather than provides an adaptation to the enduring patterns of nature. So far, the world undersea is invisible to the people of the Fjord City. After closely inventorying the transition between land and sea, I find few places offering possibilities for tactile physical contact with water.

44 (Borgen, 1966, pp. 26, 33; Translated by Elin T. Sørensen)
45 (Oslo Havn, 2011, pp. 8, 37; Translated by Sørensen)
46 (Oslo Havn, 2011, pp. 104-105; Oslo kommune Byantikvaren, 2008, p. 16; Both translated by Sørensen)
47 (Kolstø, 2013)
48 (Kolstø, 2019)

For the most, the distance between the quay top and the water surface is between 2 and 4 metres. Its seafloor is excavated to make place for heavy cargo traffic in accordance with international harbour standards of water depths of at least 8 metres. Despite reclaiming this space for mixed-use urban development, the industrial landscape is kept. In reflecting industrial building technologies and economic considerations including maximized space utilisation, the adjustment to a human scale is seemingly forgotten. Any genuine effort to re-naturalise the urban intertidal and the landscape undersea is absent.

As the backdrop for imagining future landscapes, the above passage sheds light on a moment in history when Oslo's coastline was recast into an industrial landscape. Now, it is time to turn our eyes in the opposite direction by restoring the landscape to accommodate a broader set of interests than the urban development practices of today exhibit.[49] One can only imagine the potential for a multispecies coastal community if this waterfront renewal included the facilitation for a marine megalopolis undersea. Regarding this, the next parts of the thesis and paper #3 introduce some possible ways to go.

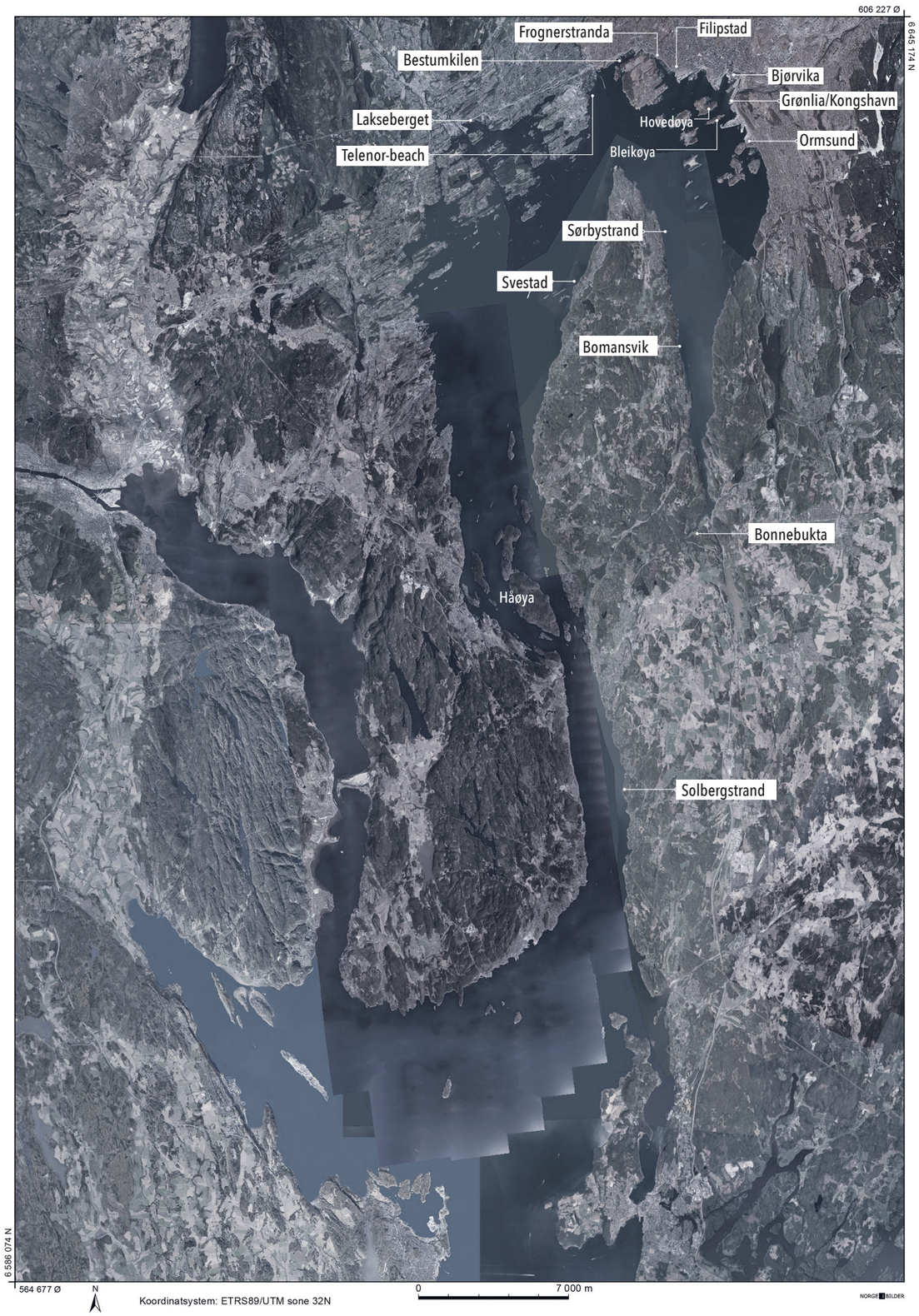
Oslo's intertidal and urban sea areas

An entirely new perspective is needed. This thesis' explorative journey has taken its departure in a sensory fieldwork: the inner Oslofjord's tidalscape has been felt, smelled, seen, heard and documented through photos under and over water, audio- and video recordings and photogrammetry. The first expeditions followed the Harbour Promenade from the first sequence starting at Frognerstranda to its endpoint at Grønlia/Kongshavn, which all together ties the Fjord City together from west to east by a nine-kilometre stretch. The landscape has been studied through the changing seasons between 2017 and 2020, with special attention to the urban sites still undergoing transformation. The fieldwork area, seen as a landscape, comprise the following locations: Lysakerfjorden including Lakseberget and the Telenor-beach at Fornebu in Bærum municipality, a suburb of Oslo, located on the west coast of the city. At these sites, at the time of the study, there were plans for establishing new landscapes based on the reuse of surplus rock masses from large infrastructure projects.

- Hovedøya, Bleikøya and Håøya, islands off the inner Oslofjord; natural rocky shore, Cambro-Silurian and granite geotopes.
- Svestad, at the Oslofjord-side of the Nesodden peninsula; natural rocky shore, granite geotope.
- Bonnebukta bay at the mouth of the Bunnefjord with Bonnbekken's outlet; Bomansvik and Sørbystrand with Sørbybekken's outlet – both small beaches along the Bunnefjord. This fjord is the innermost part of the Oslofjord, located east of the Nesodden peninsula; study of soft bottom riverine habitats and granite geotopes.
- Bestumkilen and Frognerstranda/Frognerkilen with Merradalsbekken's, Hoffselva's and Frognerelva's outlet at Skøyen, a district on Oslo's west side; Filipstad towards the Oslo city centre. Fjord City renewal sites.
- Bjørvika, Oslo city centre: Operastranda (urban beach) and Sukkerbiten by Akerselva's outlet; the new urban quarter in Bispevika and the urban commons Kongsbakkealmenningen, Sørenga, Lohavn and Loallmenningen. Fjord City renewal sites.
- Grønlia/Kongshavn with Alna's outlet, a coastal neighbourhood/transformation site to the North-East from the city centre. Fjord City renewal site.
- Nedre Bekkelaget, a coastal neighbourhood to the South-East of Oslo city centre: Ormsund strait and Ormøya, an inhabited island in the inner Oslofjord. These are the sites for the art project "Under/sea" (2019-2022).
- NIVA Research Facility at Solbergstrand, located near the Drøbak Strait, south of Oslo.

Map on the opposite page: The inner Oslofjord fieldwork area. Map retrieved from norgeibilder.no, February 2020. Flo/Sørensen 2020.

49 (Rinde & Sørensen, 2019)



"Water is truly a transitory element. It is the essential ontological metamorphosis between heaven and earth. A being dedicated to water is a being in flux."[50]

Wonders between land and sea

If you let nature be your mentor, you must revisit your chosen site time and time again, until the place is etched into your consciousness. I have done it. And now, when I close my eyes, I see each tidal place before me. Boulders of all sizes, sand grains and shells. The swells that wash over rock formations or withdraw from a gently sloping beach. I can imagine how the irregular and undulating shore orchestrates the ocean soundscape. Now I know what this landscape is about, not just intellectually, but through all of my body.

Early in the process of this thesis, I learned from making a mistake. After claiming — in an interview about the urban bluescape — that the sea was silent along its urbanised edge, I instantly felt uncertain.[51] From this point onward, and to assure myself, I stayed as much as I could by the fjord — at different sites, times of the day and seasons — to feel and listen. If someone asks me again about the sound of the urban intertidal, I know exactly what to say: the spatial qualities of the natural rocky shore facilitate the ocean sound that many of us long for, very much unlike the vertical and smooth walls of the urban edge that "silences" the sea.

When something really must be figured out, I use this method of engaging my senses deeply. In this way, landscapes, for instance, grow into my consciousness and guide me towards integrating their distinctive features into new landscape designs. Hence, to achieve my aims with this thesis', I had to challenge my land-bound senses by immersing myself below the surface of the sea. How easy it is to just let your body move with the waves rolling into shore. What you will find is that this symbiosis of sea and shore is full of wonders. Through snorkelling, I have come to know a new world of life forms and colours, such as the yellows, greens and browns of sea wrack and the floating motion of the clear green leaves of eelgrass. Beside rock pools on the shore, I can linger for a long time to study these miniature universes: like the tiniest of crabs, less than 5 millimetres in body size yet perfectly developed, moving sideways along the rocky walls, encountering trans-parent shrimp-along their way; or miniscule barnacles using their super thin fan-like feet to sweep plankton and detritus from the water into their mouths. All together these perform a mesmerising spectacle.

Passionate immersion

At the start of this exploratory journey, a short evocative text portraying the world of the sea took my breath away when I discovered it. By reading Rachel Carson's "Undersea," I became literally submerged: "To sense this world of waters known to the creatures of the sea we must shed our human perceptions of length and breadth and time and place and enter vicariously into a universe of all-pervading water."[52]

Through her writing, Carson encouraged her readers to see the marine environment from a new and even nonhuman perspective. Her last book, "The Sense of Wonder," published posthumously, is described as a "gift to the remembered child in all of us," as Carson here "captures the essence of the wonder-filled world of children and stirs in us that ancient longing for unity with the living world."[53] In this book, she states that when we seek to learn about nature, we should choose to feel rather than to know: "If facts are the seeds that later produce knowledge and wisdom, then the emotions and the impressions of the senses are the fertile soil in which the seeds must grow."[54]

50 (Bachelard, 1999/1983, p. 213)
51 (Ellingsen, 2018)
52 (Carson, 1937, p. 322)
53 (Carson, 1998/1965, p. 9)
54 (Carson, 1998/1965, p. 49)

This attitude is described as an ethic of wonder that pushes our awareness beyond ourselves. By entering the natural environment through such learning processes, we become increasingly receptive towards the fact that we are "linked to a vast ecological community inherently worth preserving and protecting from depletion."[55]

This dedication to wonder spoke to me, as I recognize myself deeply in this form of discovery. Getting to know the intertidal and its inhabitants simply by being with them has changed my way of experiencing and thinking about this landscape.

Another source of inspiration in this regard, was reading about Barbara McClintock, who received recognition as a Nobel laureate for work on mobile genetic elements. She claims that her discoveries in plant cytology — the study of the structure of the cell — are due to an ability to acquire a "feeling for the organism," by which one become open to "what the material has to say." Through closely identifying with the material she received new insights that she later could synthesize with observations and explanations grounded in more traditional scientific methods.[56] By immersing herself and trusting a keen intuition, McClintock created new knowledge. In my practice, this kind of interaction with a material, or an area of study, is an essential tool for concept development. Within the process of idea development, you must sometimes dare to follow seemingly insignificant clues might very well turn out to be important building blocks in the work. Sensuous intuition may function as empathetic leverage, increasing the probability of innovative breakthroughs. So, to transform the world and change it for the better, we must reach beyond expectations and business as usual. Here immersion into wonder is one tool to break habits and open our minds. Regardless of what you seek to learn from, engaging in the sense of wonder is an essential tool for a landscape architect.

Multisensory learning through mapping and visualisation

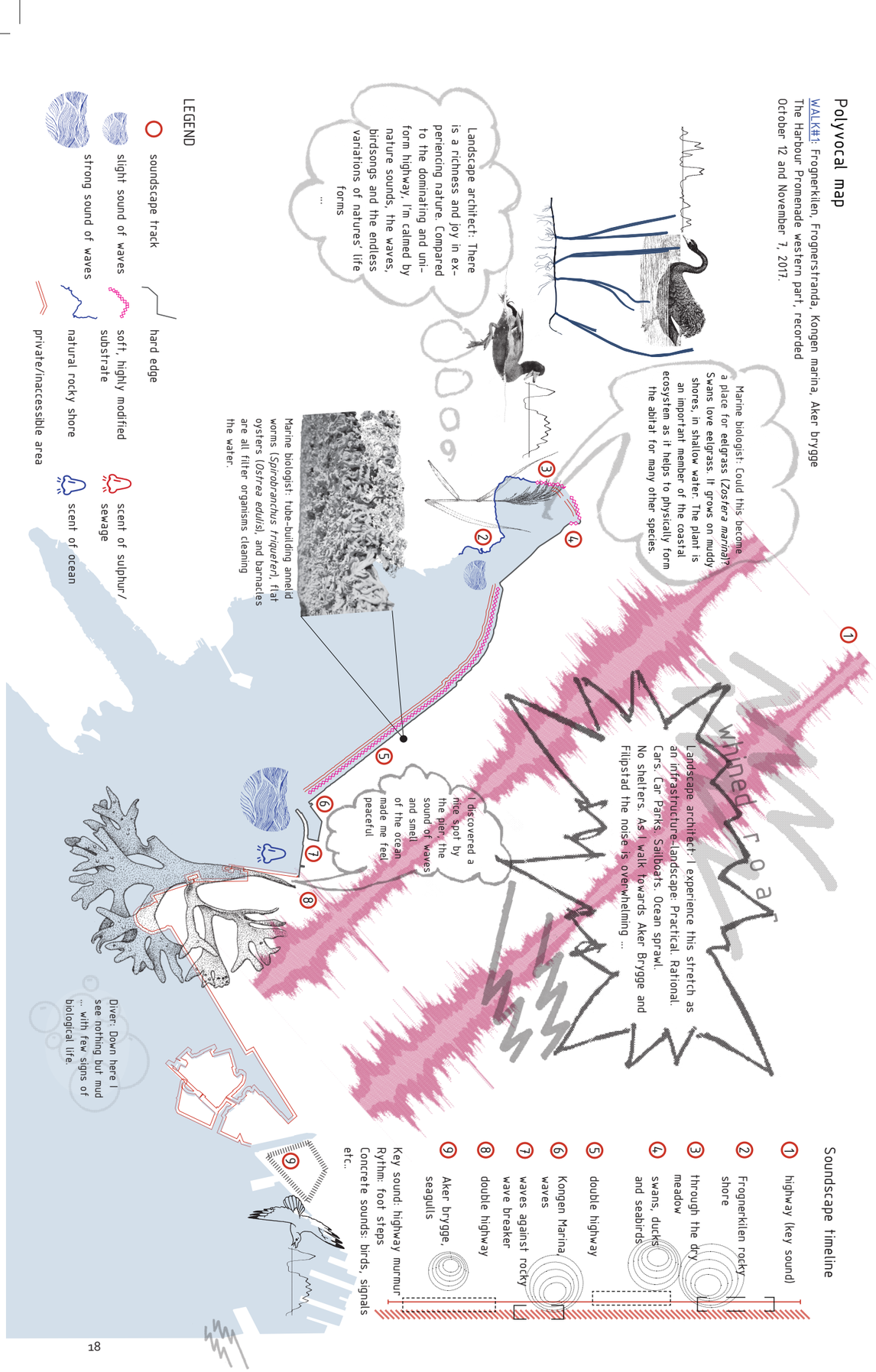
Architectural presentations of the sea are mostly one-dimensional. This has to do with how the landscape is explored and visualized. Due to tight progress plans and the regime of billable time, our field tends to apply well-established methods without having time to critically reflect upon them. There is a tendency to automatically limit oneself to what technology allows for, such as googling a place instead of experiencing it yourself. Sensing the landscape becomes especially critical when addressing a landscape that is generally overlooked — like the urban sea areas and the urban intertidal: the area of a seashore which is covered at high tide and uncovered at low tide. Since there are no established checklists for this transition zone, this is where passionate immersion as method comes into its own. The thesis' mapping and landscape visualisations seek to challenge the present trend. I have sought to experience the intertidal as one unified landscape. Since nature is inherently dynamic, I extended my senses using time-based media. By means of multisensory learning through mapping and visualisation, I have aimed at giving this landscape a "voice." Therefore, a poetic language for the dynamics of landscape is explored through using living pictures and animation.

By walking, wading, swimming, snorkelling, sensing and recording along and within Oslo's urban sea areas, the applicability of multisensory methods to a landscape architectural practice has been investigated. This has been transformative for my perspective on and knowledge of the in-between space of the intertidal.

55 (Stitt, 2019)
56 (Mullin, 2011, p. 157)

Polyvocal map

WALK#1: Frognerkilen, Frognerstranda, Kongen marina, Aker brygge
The Harbour Promenade western part, recorded
October 12 and November 7, 2017.



The hegemony of the eye

The design of lived and built environments clearly involves all the senses — sound, sight, light, smells, touch, season variations, heat, taste, etc.[57] Architectural production relies upon extensive analyses including studies of the sun, shade, light, wind, energy and comfort metrics. However, from my training and practice as a landscape architect, I find much of the work to rely upon the gaze. For example, during site visits we extend eyesight through a camera lens and perform site evaluation and analyses by looking at photos and aerial maps. The site's sounds, smells or tactility are seldom the focus of urban development team meetings. Yet, I believe facilitating for experiencing the tactility and dynamics of landscapes is essential to creating good neighbourhoods and to safeguard well-being in the city. The hegemony of the eye is a topic within academia too. Here, multisensory types of inquiry are described as encompassing "attention and intention, meta/physical and socially embodied processes without falsely ignoring the body, separating the mind from body, or splitting material-physical and social worlds."[58] Staying within the two-dimensionality of photos, maps and texts felt limiting to my practice. Photos and map sections are piecemeal abstractions, quite contrary to the spatio-temporal living participants in landscapes — such as people and marine life.

Being with a place is about becoming constantly influenced by so many impressions that are simultaneously at play: a sudden draught flowing between tall buildings. Spatial qualities transformed at night. A cold shade. The wind abruptly picking up and whipping hair about your face. The sound of hail hitting the ground — or the gust from a roaring trailer on the highway.

Polyvocal maps

Addressing the urbanscapes' sonic realm, the first sensory fieldwork comprises walks along the Harbour Promenade during October and November 2017. The three first sonic walks took place under a crisp sun, and the last on a snowy, windy and foggy day. To refine my sensitivity, I started out with an *ear clearing*, that is, by folding the palms of one's hands around the ears like a funnel and turning the head from side to side. In this way you can tune into the audible sides of the urbanscape, focusing your attention on the place's atmosphere. Next, I took an opposite strategy, heightening my sonic sensitivity by *augmented listening*, that is, by listening to the place through a recording device amplifying the sound impressions. These are some techniques that can be used to heighten awareness of urban ambiance. From that time onward, my practice was all about sensing and recording. While editing the raw material of concrete sounds into soundscapes, I had an aha!-moment. Never had I realized how different the various sequences along the Harbour Promenade sounded. Links to "Sound Walk#1:" https://freesound.org/people/elinso/sounds/412124/ and "Sound Walk#2:" https://freesound.org/people/elinso/sounds/412129/ .

Two polyvocal maps and soundscapes illustrate these experiences. These audiovisual works were the first attempt to "voice" the urban intertidal. The maps are made as assemblages of photos, audio-files and drawings. As can be seen on the opposite page, they include onomatopoetic utterances and non-words like "chirp, cheep, squawk" from seabirds, or "clang, buzz, clank" from construction work. To tell about the places, I have also used thought and speech bubbles containing statements from planning documents and excerpts from field notes.

Living pictures

Whilst virtual simulations and state-of-the-art visualisations are indispensable tools in the prediction and planning of environments, I claim that they can't compete with experiencing reality through emotions and the impressions of the senses. The best way to grasp these multitudes of perceptions is by either observing or physically testing how things influence each other at a 1:1 real-life scale. Regarding movement, I have used simple animation techniques to create images and maps that move across time, through different weather conditions and extreme climate events. Map-animation has served as a way to learn, reexperience and convey how the landscape works and changes.

57 (International Ambiances Network, 2020)
58 (Daza & Gershon, 2015, p. 539)

By example, Sjursøya's aforementioned fate; or by letting the fluvial geomorphology of Bonnebukta bay be my teacher in order to investigating possible ways to reclaim riverine qualities for the redirected Alna River. From my geo-mentor I learned that his bay is a prime example of a fluvial-influenced delta, hence, an applicable role model for restoring fjord rivers such as Alna.[59] By putting together aerial photos from 1956 until 2019, these waterscape dynamics become visually clear. In this way, the living pictures provide some clues to how urban waterscapes must be designed in order to become more functional and hence resilient.

Eyes undersea

After walking and wading along Oslo's developed foreshore, I had to break the water's surface. Since diving was unfamiliar to me, I started by contacting local diving communities in search of someone who could provide local knowledge and to be "my eyes" underwater. I arranged site visits with some of these divers and started planning a collaborative effort at documenting the underwater conditions of certain locations within Oslo's urban sea areas. In order to succeed, however, many unpredictable factors must come together at a specific moment, and as the following reveals, underwater photo sessions are nearly impossible to plan.

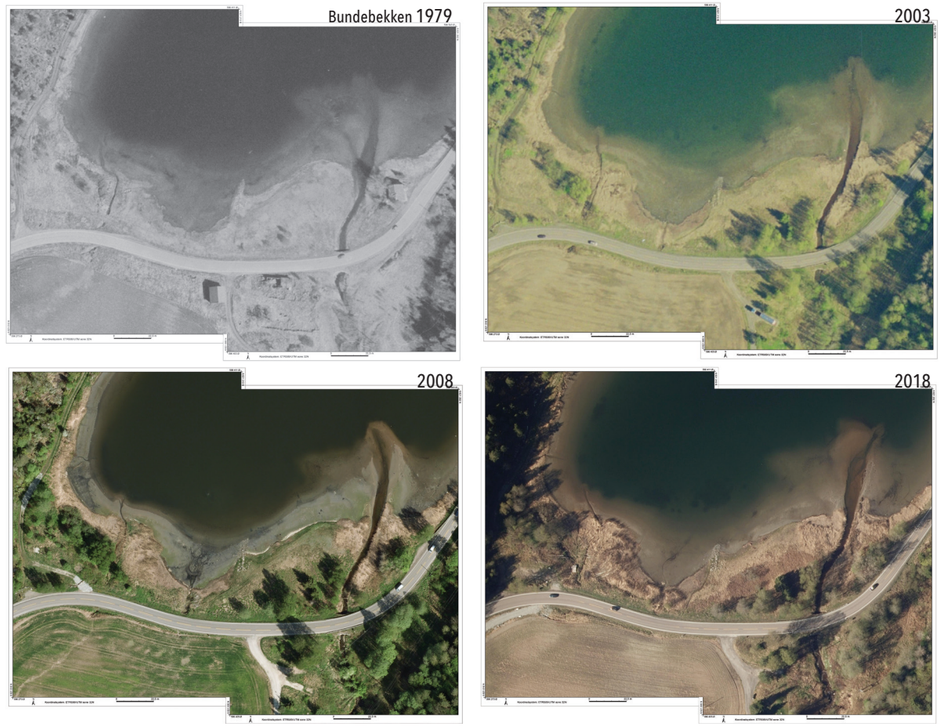
For safety reasons, a diver must always be accompanied by a buddy and strictly follow CMAS International Diver Training Standards and Procedures.[60] Among other things, depth and water pressure influence the duration and number of dives. With diving comes heavy scuba equipment, hence, the diving site must be accessible by car or boat. The diving vessel must be moored well, and you might need a skipper. Visibility is another challenge you soon encounter. In studying something undersea, you quickly learn about the phenomenon of underwater vision and how sunlight behaves in water. Underwater visibility relates to the water transparency measure which depends on the combined effect of the scattering and absorption of light by the water surface, as well as the density of suspended part-icles and marine organisms in the water column. For example, particles in nutrient-rich surface water may result in upward-scattered light. Compared to taking photos on land, underwater photography comes with the challenges of motion blur, low light and again poorer visibility, and within Norwegian waters the challenges are intensified by the low sun angle and algae growth.[61] Any experienced diver knows about algal blooms during summer, so, winter may be a better time to see the landscape undersea. However, this is the coldest time of year, calling for even more preparation and equipment. Wind is yet another factor. A stiff wind may contribute to swirling up sediment from the bottom, limiting the light and again reducing the visibility.[62]

To achieve my goal, I tried to hire boats, avoid unstable weather, consult tide charts, adapt to people's working hours and available free time, gather information and map out sites, accessibility, requirements for permits etc. After months of planning and organizing that led nowhere, I eventually realised that I had to take matters into my own hands. From that moment, a camera, swimsuit and snorkelling gear were always ready at hand.

Seeking to become one with the water

During the summers of 2018 and 2019, Oslo's urban sea areas were explored below the water surface, aided by a GoPro HERO Session waterproof digital action camera. Much inspired by the hallucinatory documentary "Leviathan," [63] directed by the anthropologists Dr. Lucien Castaing-Taylor and Dr. Véréna Paravel, both affiliated with The Sensory Ethnography Lab at Harvard University.[64] With the GoPro's fish-eye lens strapped to their heads, both the filmmakers and crew capture life onboard a commercial fishing boat. I share journalist Philip Hoare's description from a newspaper article: "The filmmakers and crew recorded the raging midnight seas from which are hauled the fish and scallops that will end up on china plates and linen tablecloths in smart restaurants. Remorselessly, they expose every aspect of this visceral business — often conducted in the dark [...] It is a weird otherworld, filled with bug-eyed fish slathering over the decks, clanking rusty chains and hooded figures like medieval torturers, all perpetually doused by the rising Atlantic. [...]

59 (Nystuen & Sørensen, professional dialogues 2017-2020)
60 (CMAS, 2020)
61 (Kvalø & Wammer, 2018, p. 9; Translated by Elin T. Sørensen)
62 (Kvalø & Wammer, 2018; Translated by Sørensen)
63 (Castaing-Taylor & Paravel, 2012)
64 (The Sensory Ethnography Lab, 2020)



Stills from the flip animation "Bundebekken," a study of the fluvial morphology of the stream's outlet in Bonnebukta. The work is based on aerial photos from 1956, 1979, 1988, 2003, 2008, 2011, 2013, 2014, 2016, 2017 and 2018, retrieved from "Norge i bilder" February 2019. The animation can be viewed at RC: https://www.researchcatalogue.net/view/848167/971677 Elin T. Sørensen © BONO 2020.

Shrieking gulls plunge up from the dawn-slashed sky in vertiginous, inverted scenes as the cameras tumble upside-down."[65] Seeking to become one with the water, I too attached the GoPro to my body. I had to practice keeping calm and letting the movement of the water guide me. During the postproduction, inspired by "Leviathan," I included the abrupt movement and incidents resulting from not seeing what you are filming, such as up-side down scenes and scenes where I or the camera crash into things. The editing is raw and unpolished, like the experiences themselves. The previously mentioned twenty-one samples show a range of conditions underwater, from barren seawalls to the rolling waves and their effect upon the blue forests and shore crabs hungrily devouring barnacles.

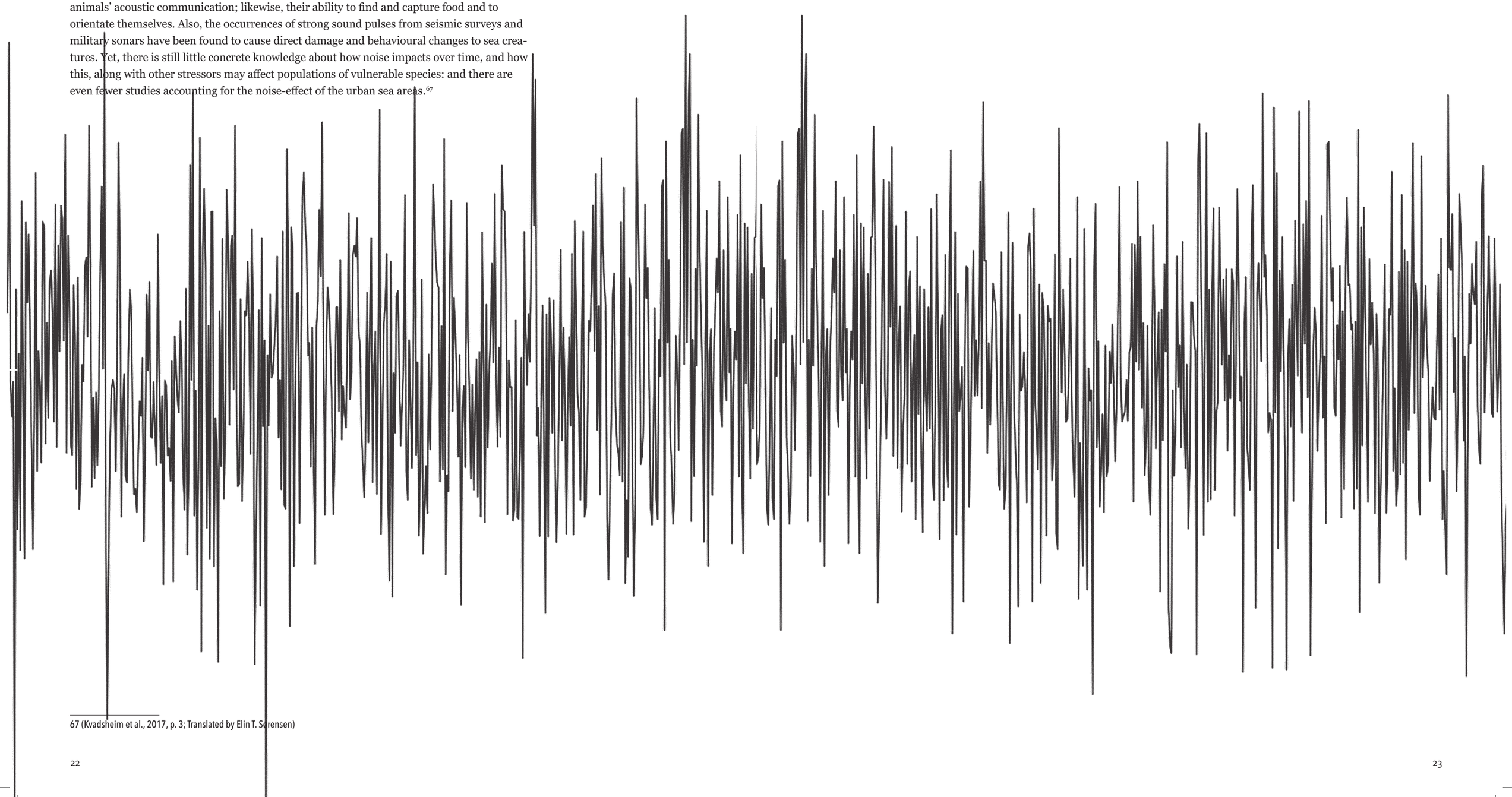
The visual documentation of the status of Oslo's urban sea areas was eventually shot by me and some of my collaborating partners. As part of the joint project with NIVA and the subsequent report, we surveyed the urban sea areas of the Fjord City with a Blueye underwater drone.[66] Another Blueye-recording was made together with diver Petter F. Schmedling to study the concrete reefs at 28 meters depth beneath the Tjuvholmen residential area. Here we found that the artificial reefs were covered by the beautiful feather duster worm (*Sabellidae*). The undersea fieldwork comprises the first tidal expeditions at Sørbystrand granite geotope by Bunnefjorden in 2018, followed by recordings with NIVA in October 2019. These time-based techniques clearly afford an extension of the senses, and the impressions can be viewed at RC: the greedy shore crabs at Solbergstrand https://www.researchcatalogue.net/view/869494/884065 and the undersea fieldwork https://www.researchcatalogue.net/view/848167/848207 — with the feather duster worm at Tjuvholmen found in video #12.

65 (Hoare, 2013)
66 (Rinde & Sørensen et al., 2019)

Blue noise

The initial idea was to use the GoPro camera to aid my sight, and as an analytical device to later rewind back and forth to study the undersea environment more closely. However, the camera automatically records sound with its builtin microphone, and thereby facilitates augmented listening of the soundscapes undersea. This resulted in a second epiphany — the urban undersea soundscape. Not only was I dazzled by the variety of landscape experiences under the surface — spanning from wastelands to lively nature — but was literary struck by the city-noise reaching down below.

Over the last fifteen years there has developed a growing body of research about how marine environments are affected by human-induced noise. One problem is background ambient noise, primarily due to shipping. The noise pollution often interferes with, or masks, animals' acoustic communication; likewise, their ability to find and capture food and to orientate themselves. Also, the occurrences of strong sound pulses from seismic surveys and military sonars have been found to cause direct damage and behavioural changes to sea creatures. Yet, there is still little concrete knowledge about how noise impacts over time, and how this, along with other stressors may affect populations of vulnerable species: and there are even fewer studies accounting for the noise-effect of the urban sea areas.[67]



67 (Kvadsheim et al., 2017, p. 3; Translated by Elin T. Sørensen)





Exploring a poetic language for landscape dynamics

In most architectural renderings, waterscapes are depicted flat and blue, hence, hiding everything that is relevant for being able to interact with undersea landscapes in a sustainable way. As a response to this, the thesis' visual works are motivated by a wish to make living tactile representations of tidalscapes. As mentioned, moving pictures play a decisive role in capturing ephemeral variations such as day cycles or extreme climate events. To evoke feelings of empathy, I have deliberately chosen to dramatize the landscape visualisations. Seduction and drama are well-known features of architectural visualisation for the sake of convincing both developers and customers, often created by means of advanced 3-D renderings.

I have approached the visualisation task differently than what is usual in current planning and design practices. Seeking to trigger emotional recognition of the urban seashore, I have explored a poetic language. In evocative illustrations, technical AutoCAD-drawings are mixed with handmade textures and colour effects. Yet, regarding the expected form of communication within the architectural industry, I have also chosen to render designs by means of digital fabrication. This process is recounted in Part II.

Inventorying the transition between land and sea

As part of the multisensory fieldwork, Oslo's artificial shoreline was analysed. This step in the investigation marks a transition from merely sensing to understanding the properties of the urban intertidal, thus laying the foundation to be able to communicate, visualise and eventually make new designs. In the period 2017-2019, the Fjord City's artificial shore was examined as it still is today. The result is an edge-inventory showing the qualities of the boundary between the city's hardscape and the fjord. The survey has been carried out with assistance from landscape architect student Runa Tunheim, and the finds are elaborated through the making of the NIVA and NMBU report on behalf of the City of Oslo.[68] Through this work, among other things, Eli Rinde and I developed terms characterizing the qualities of the urban intertidal. The analysis expresses today's situation contrasted by a vision for the future and a novel conceptualization of this landscape.

68 (Rinde & Sørensen et al., 2019)



From revisiting my childhood favourite "Who Will Comfort Toffle?", it is Jansson's lonely Toffle – standing on a beach, contemplating amongst blue mussels and a conch against the pink night skies – who led me further in my search for ways to trigger emotional recognition of the urban seashore.

Three versions of evocative landscape drama. Above: Toffle at the beach © Tove Jansson 1960 Moomin Characters™. Opposite page, left: The contemplation of nature, whereby the landscape mirrors the viewer's inner state in the iconic romantic painting "Wanderer Above the Sea of Fog" by Caspar David Friedrich from 1818, retrieved from Wikimedia Commons the free media repository 2020. Opposite page, right: Seduction and drama in "Star Observatory," designed by Nicodemos and Elena K. Tsolakis of Kyriakos Tsolakis Architects. The rendering is made by MIR. Norway's leading architectural visualization studio who makes portraits of unbuilt architecture. The work is reprinted by permission from MIR. and the architects.

The proposals for enhancement include, among other things, undersea stepping-stones for marine creatures — potentially providing a blue-green connectivity in the sea. The overview of today's situation is made by calculating the linear extent of the different types of edges between Frognerstranda and Kongshavn/Grønlia, such as the stretches of natural rocky shore along the Bygdøy peninsula of the bays Bestumkilen and Frognerkilen, and the *uniform shoreline designs*, such as the *listed stone masonry walls*, *massive quays*, *uniform landfills* and the two *urban beaches*. The map and bar chart for the future visualise two possibilities: the first approximates an *organic shoreline formation that mimics the natural rocky shore* (light-blue colour bar). This design is suggested for all parts of the artificial shore that today consists of urban waste rock fill. In the other, the *uniform artificial shoreline of existing developments* is calculated as well as the the footprint of the proposed new masterplans for the remaining renewal sites. For these sites, it is suggested to offer *diversity-promoting and three-dimensional marine habitats* as integrated parts of the new building quartiers. The potential area for establishing *multispecies neighbourhoods* with living spaces for marine life and people in these places is calculated in hectares. For comparison, the area-factor obtained by these measures equals the demands of the Bjørvika-redevelopment which required 50 percent green rooftops on the series of office buildings called Barcode.[69] In the visionary map, a similar strategy is suggested for life undersea. In any case the two bar charts in the figures on the next page, clearly show that the new designs would result in an a more diverse tidalscape.

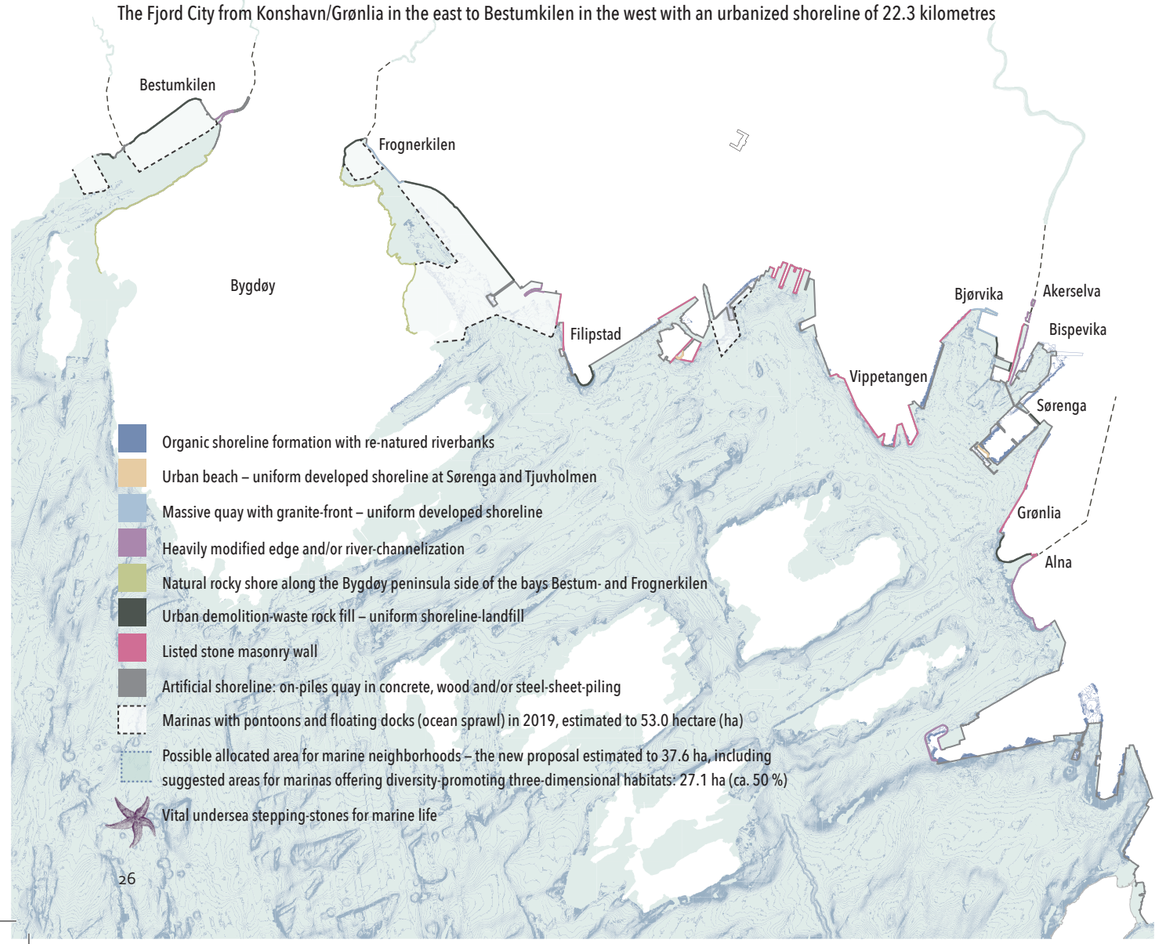
69 (Noreng et al., 2012, p. 12)





Left: quay with granite-front at Frognerstranda. Middle: listed stone masonry wall at Grønlia. Right: demolition-waste rock fill by the Alna river. Photos by Elin T. Sørensen.

The Fjord City from Konshavn/Grønlia in the east to Bestumkilen in the west with an urbanized shoreline of 22.3 kilometres

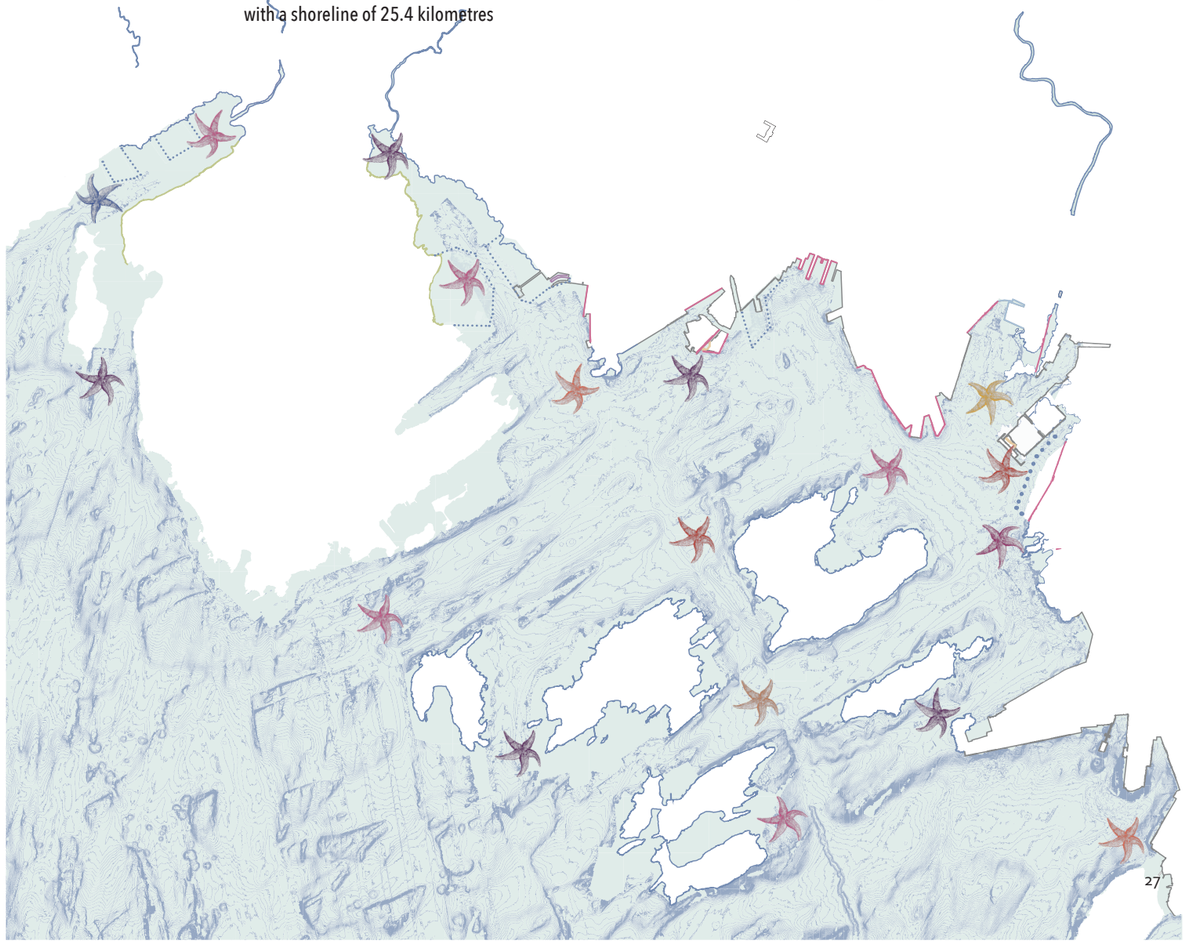






Flood in Frognerkilen February 17, 2020: the walking and biking trail along the bay is completely submerged. Photo by Øystein Aurlien.

New visionary proposal from Konshavn/Grønlia to Bestumkilen with a diversity-promoting amphibious tidalscape with a shoreline of 25.4 kilometres



Landscapes with a soul

The animated sequences in the video "Landscapes with a Soul" build on the examination described above. The imagery has watercolour backgrounds that make the bodies of water vivid, and motion is created by means of a simple animation technique-where the changing imagery is structured around a set of key drawings, called the animation extremes. To manage the movements and actions within a storyline, the animator starts with these extremes as a rough basis for the animated sequences. In-betweening is the process of generating intermediate frames between key events. The illusion of motion, and thus the narrative structure, appears through the variation of rough and smoothly evolving transitions. The use of these visual effects is motivated by a desire to grasp the intangible qualities of landscapes. It has been a way to envision for myself, as well as to show to others, the transitory stages of landscapes, such as the vertical land motion, the day cycle, the extensiveness of human interventions, extreme climate events. One sequence, for example, illustrates the potential scale of inundation at two Fjord City renewal sites. The landscape animation is considered a pilot, hence, in the language of animation, this video would be called a *rough version* waiting for inbetweening.

From hand-drawn narratives to high-end computing – and back

Animated maps initially appeared as hand-drawn narratives for war propaganda newsreels in the late 1930s.[70] Today, the cyclic, pulsing nature of the seasons and environmental changes are captured in mesmerising projects based on advanced computing, such as "Our Perpetual Ocean" — an animation showing ocean surface currents between 2005—2007 recorded by NASA satellites. This animation offers a realistic study of the order and the chaos of the circulating waters that populate Earth's ocean. "Here model-data syntheses are being used to quantify the ocean's role in the global carbon cycle, to understand the recent evolution of the polar oceans, to monitor time-evolving heat, water, and chemi-cal exchanges within and between different components of the Earth system, and for many other science applications."[71] "Our Perpetual Ocean," in a version adapted for the artwork "Kaurene" (2013-2014) can be viewed at RC: https://www.researchcatalogue.net/view/848167/962380 .

Given the scope of this thesis, the landscape visualisation is simpler and more poetic. In fact, the thesis' graphic design is inspired by Tove Jansson's naïvistic, yet advanced and ingenious visual universe. Jansson is a celebrated graphic artist whose work demonstrates a high degree of visual intelligence. Humour in combination with deep existential issues run through her oeuvre. The precision in her landscape depictions suggest a close relation to nature, in particular coastalscapes. For almost thirty years, Tove Jansson and her partner Tuulikki Pietilä lived on the tiny rocky islet Klovharu off the coast of Porvoo in the Pellinki archipelago, in the shallow Gulf of Finland.[72] Jansson's use of colour is astonishingly effective in creating drama and mood. An example is the way she combines purple and orange or yellow and blue to express different times of day to drive the plot forward. Her way of expressing weather and light phases — such as calm or stormy weather, the golden hour or twilights — informs "Landscapes with a Soul." Jansson's excellence in storytelling and imagery has served as a guide for this thesis' landscape visualisation. What is more, by her rendering of seascapes, I have become more receptive towards the ever-changing ambience of landscapes.

Capturing waterscape dynamics

The figures on the next page show a selection of images from "Landscapes with a Soul", rendering different situations at the sites Frognerstranda and Grønlia/Kongshavn. These locations constitute the endpoints of the Harbour Promenade which form the outer boundaries of the Fjord City. The animated landscape visualisations show the transition from how these areas appear today to alternative visions. The latter depict what I call an amphibious landscape design approach for the creation of urban coastscapes that can withstand future changes to the tidal regime or storm surges that may occur with climate change and rising sea levels.[73]

70 (Harrower, 2020)
71 (NASA, 2005-2007)
72 (Moomin Characters, "Tove"; Klovharu)
73 (Kartverket, 2019; Kartverket, 2020)

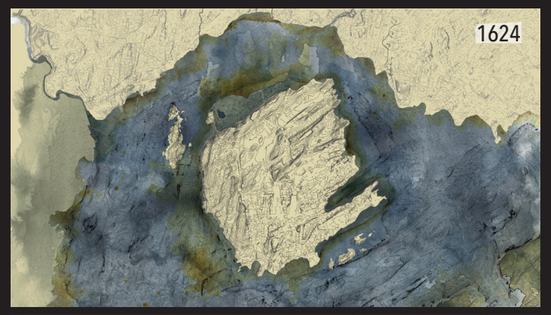
On the subsequent pages the images reneder the transition for the Bygdøy-landscape from an island to a peninsula due to vertical land motion and urbanisation. The animation builds on an analysis of historical maps and aerial photos that indicate the changes along Oslo's foreshore through different periods in time. The different shorelines are traced and overlaid with the outline of the forthcoming masterplans of the Fjord City. Finally, the different shorelines are compared to predicted storm surge data retrieved from the Norwegian Mapping Authority's web tool for mapping storm surge and rising sea levels, illustrating, for example, how the expected 1000-year flood flow rate of 2090 would affect Oslo's urban shore.[74] I was curious to see this flood water level together with the urbanised floodplains and marine estuaries, and in relation to the original coastscape before coastal hardening. The approach is inspired by the previously mentioned concept of the landscape deep structure with respect to resili- ent urban development,[75] which is also the topic of the TV-documentary "Sinking Cities."

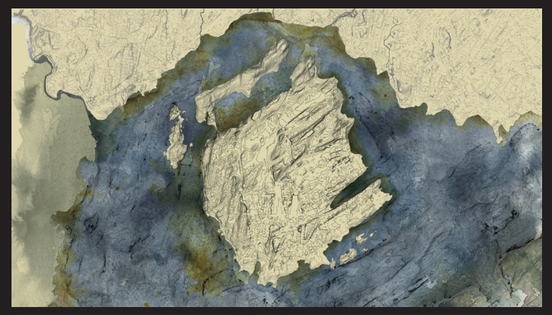
The examples put forth in the following have inspired and influenced the thesis' design propositions and visualisation. Regarding the use of animation to capture landscape dynamics, I must mention landscape architect Vidar Asheim who used an animation storyboard technique already in 1978.[76] In the book-sequence "From the Middle Ages to the present — a cartoon narrative," changes in biotopes due to land use illustrate a site-transition from harvest landscapes in the 13th century through high-productivity cultural landscapes in the 1800s to urbanisation in the 1980s.[77] The role of past processes of shaping landscapes is increasingly recognised. This is evident in "Sinking Cities," which tells the story of how five global cities are coming to grips with the effects of rising seas. In one episode, we meet geographer Matt Knutzen, who manages the map database at the New York Public Library, and Bill Johnson at the Department of Homeland Security. New York City has an 800-kilometre-long coastline, but no protection from the sea. In seeking insights on how vulnerable this cityscape is to extreme weather events, the two look for answers in the world of maps: by overlaying historical maps starting from 1860 to Manhattan's present layout, and with the storm surge data of Hurricane Sandy, they found a perfect alignment between the original shoreland and the point where the flooding decreased. As Johnson states in the documentary: "This reveals that 'Sandy' to a large degree is humanmade: the flooding came as a result of 400 years of human activity and the creation of an artificial floodplain having been densely filled with modern urban infrastructure."[78] To mitigate the challenges of a rising sea, there is unanimous agreement among the informants of the TV-documentary of the need to adopt adaptive infrastructural solutions, encouraging flexible building structures that yield rather than resist natural forces.[79] The project "The Renaturation of the River Aire" demonstrates one such landscaping approach, where the design mimics the Aires' fluvial geomorphology by adopting a pattern typical for braided rivers and allowing for the interplay between the riverbed material and waterflow to create wandering channels. Hence, the river becomes the "landscaper," and a new nature-based riverscape emerges over time. The River Aire is one example of eco-engineering at a landscape level. The project is briefly presented in Appendix II.

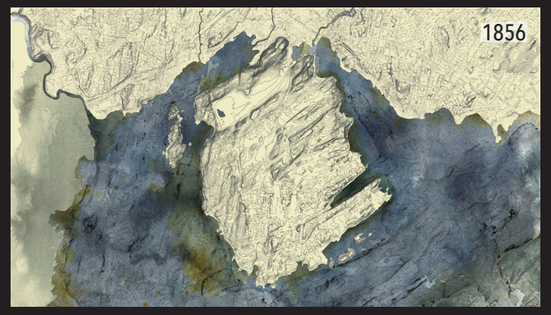
The following part of this thesis explore how the complexity of nature can be transferred to an urban context and, thus, help us to re-connect to the sea.

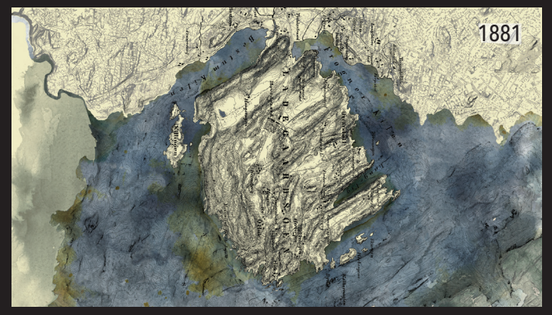
NOTE
The landscape investigations build upon land data from the database "Norge digitalt," the bathymetric data from "Geonorge" – the national site for map data and other location-based information in Norway, and the Norwegian Mapping Authority's Hydrographic Service. Sections of aerial photos are retrieved from the database "norgeibilder.no." All map data are retrieved February 2018. The data are examined and processed with the help of the computer-aided design and drafting software application AutoCAD. This software enables accuracy in scaling and measuring elements and correct distances within the created base plans and areas at a 1:1 scale, corresponding to the world coordinate system: allowing for the creation of architectural proposals which perfectly match a site location. The maps and illustrations are refined by using Adobe Creative Suite and the applications Photoshop, Acrobat, InDesign and Illustrator, in combination with watercolours and hand made artworks.

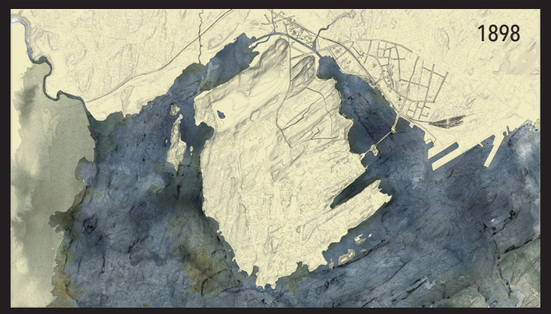
74 (Kartverket, 2019)
75 (Spirn, 1993)
76 (Asheim, 1978)
77 (Asheim, 1978, pp. 138-143; Translated by Elin T. Sørensen)
78 (Cineflix (Cities) Inc. in association with THIRTEEN Productions, 2018)
79 (Cineflix (Cities) Inc. in association with THIRTEEN Productions, 2018)

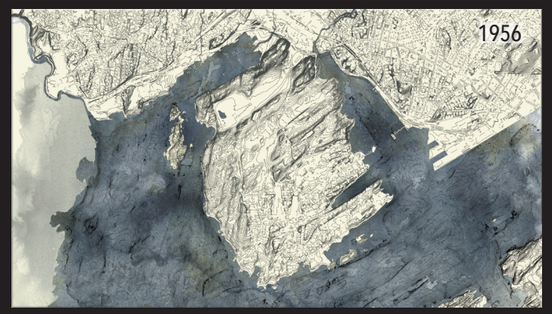


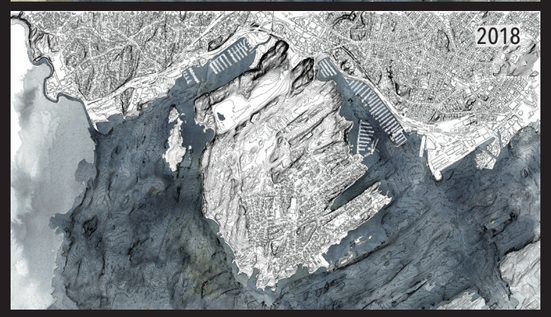


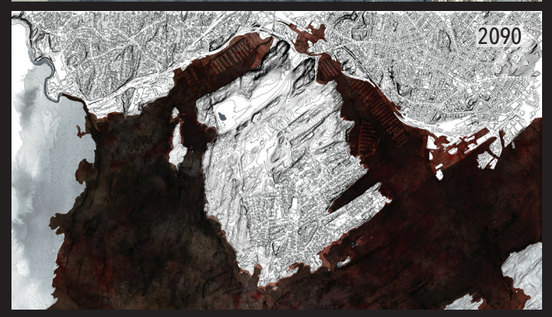












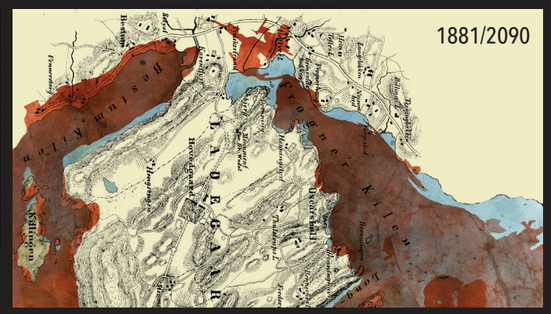


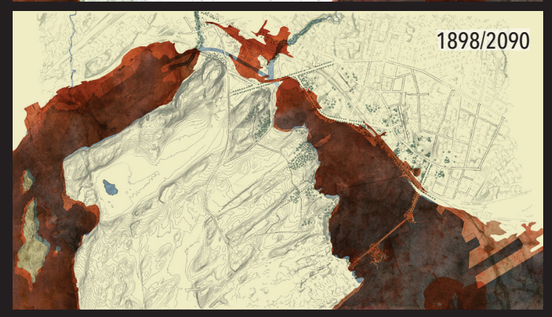














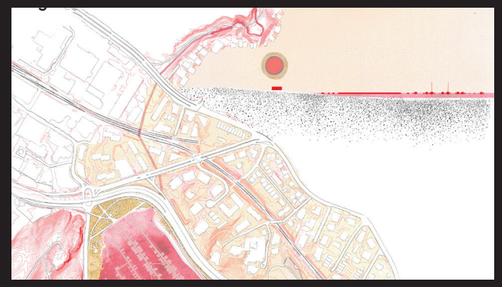
Once upon a time, the Bygdøy peninsula was amongst the isles of the inner Oslofjord. The name is from Norse, where *bygð* means an "area with houses and population" and *ey* "island." In former times, this was the only inhabited islet in the inner part of Oslofjord. Later, the land was called "Ladegaardsöen," and the bays Bestumkilen and Frognerkilen were named "The Ladegaards Fjords." Due to vertical land motion – explained by the rise of landmasses after the lifting of the huge weight of ice sheets during the last glacial period – Bygdøy eventually became a half-island that separated the bays.

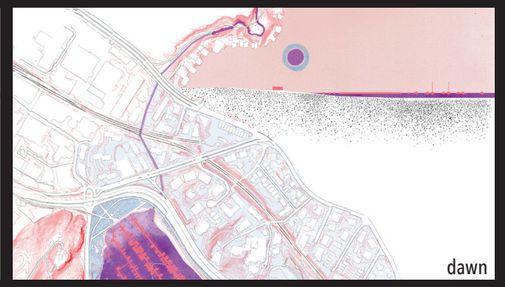
One of the proposals to the design competition for the Port development of Kristiania from 1898, shows a 20-meter-wide channel across the isthmus. In this pristine landscape the engineers connected the two waterscapes by drafting an advantageous shortcut for marine transport. As stated in 1898, "A canal at this site will be invaluable for the renewal of the inner part of the Frognerkilen bay." The pictures above show stills from "Landscapes with a Soul" based upon maps from 1624, 1856, 1881, 1898, 1956, overlain with the Fjord City's present layout from 2019, and the predicted storm surge data for the year 2090. The sequence covers the fieldwork areas from Lysakerelva in the west to Filipstad and Tjuvholmen towards the city centre.

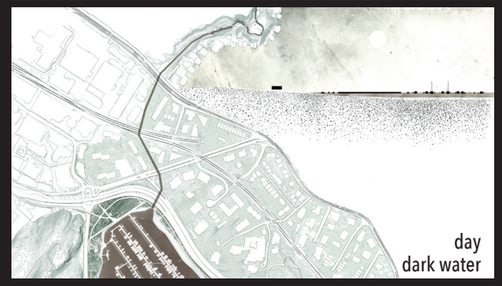
The Bygdøy peninsula is depicted in the map "Ladegaardsöen" from 1881, showing how the isle joins the mainland by a narrow piece of land. The isthmus was called "Tyskerstrand" or "Stranda," meaning beach. It is easy to imagine this area as a wetland and soft bottom habitat.

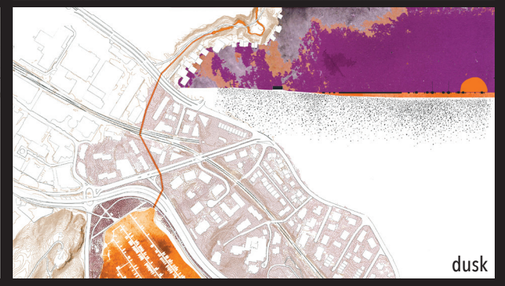
The Bygdøy Channel reappears in several proposals from the next international ideas competition in 1915 and in later master-plans as well – but it was never realized. If we look 70 years ahead in time – at the 1000 years storm surge prediction for 2090 – the two bays and their rivers clearly appear as one flooding area: overlaying the storm surge data with the historical maps and the present-day layout reveal an alignment between the original shoreland and today's flood-prone landscape. The area calls for shoreline softening: implying the implementation of soft edges, wetlands and blue forests providing for a climate proof urban bluescape. With the help of amphibious landscaping and buoyant solutions one potentially could achieve a landscape that may withstand the forces of nature.

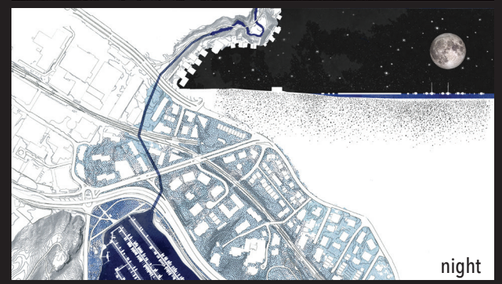
Stills from the animated pilot by Elin T. Sørensen, assisted by Runa Tunheim © BONO 2019-2020.
The pilot can be viewed at RC: https://www.researchcatalogue.net/view/848167/884169

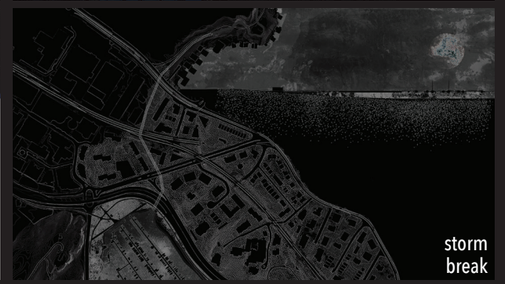


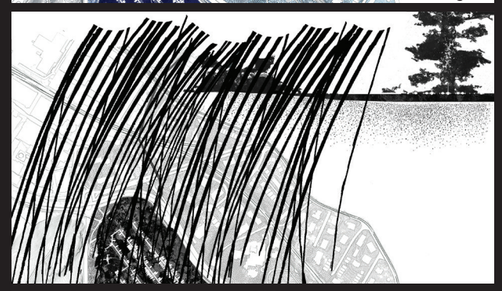


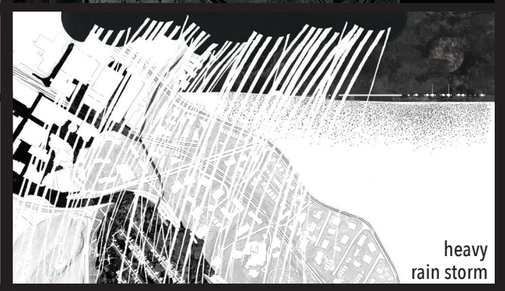


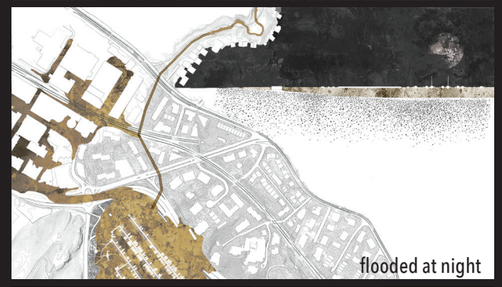


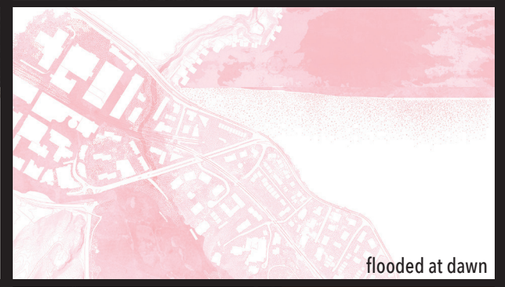




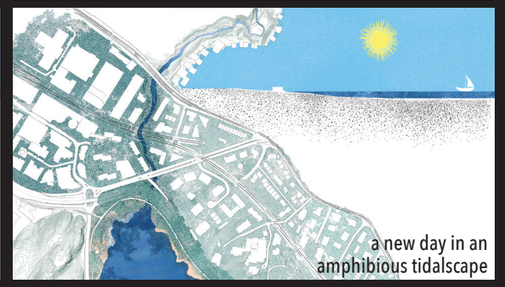




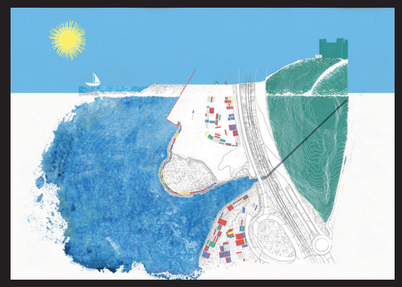


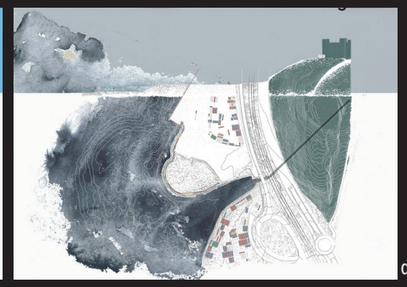






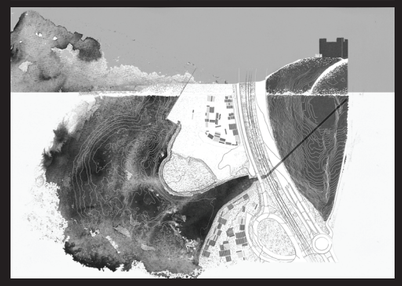
day





dusk

storm
break

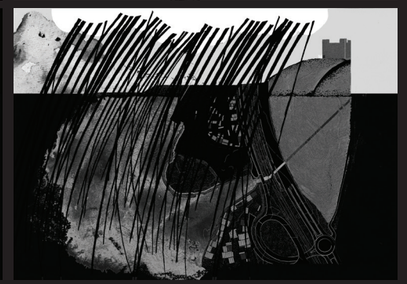


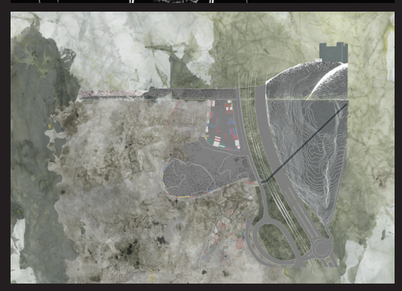


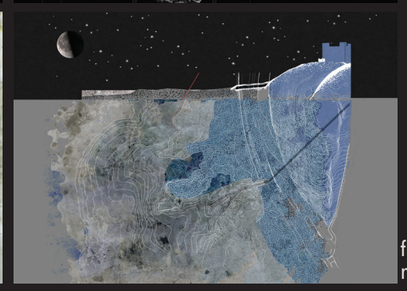
stormy
night

heavy
rain storm



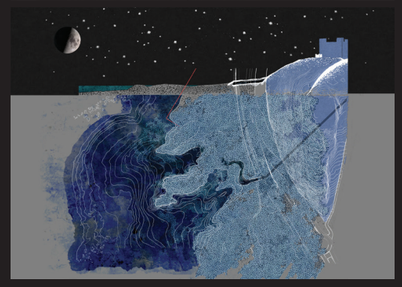


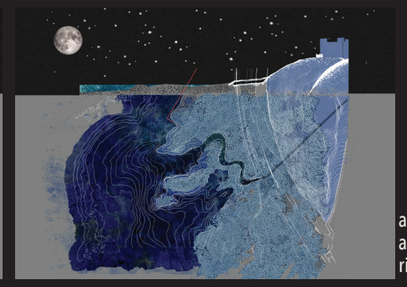




flooded
night

half moon
low tide





a new
amphibious
riverscape

The pictures on the opposite page show stills from "Landscapes with a Soul" from Frognerstranda: in the present-day layout, this urban beach is made from urban demolition-waste rock forming a uniform shore-line-landfill. The depictions to the left express different weather and light phases. At the end of the sequence, a new landscape emerges with an organic shoreline formation that mimics the natural rocky shore with blue forest, seagrass meadows and re-natured riverbanks of the Frognerelva estuary. The pictures above show the Kongshavn area, today existing as an urban demolition-waste rock fill and uniform shoreline-landfill. The future vision shows a shoreline formation modelled on nature with blue forests and re-natured riverbanks of the Alna River estuary. From the animated pilot by Elin T. Sørensen, assisted by Runa Tunheim © BONO 2019-2020.

Part II
From marine deserts to multispecies neighbourhoods

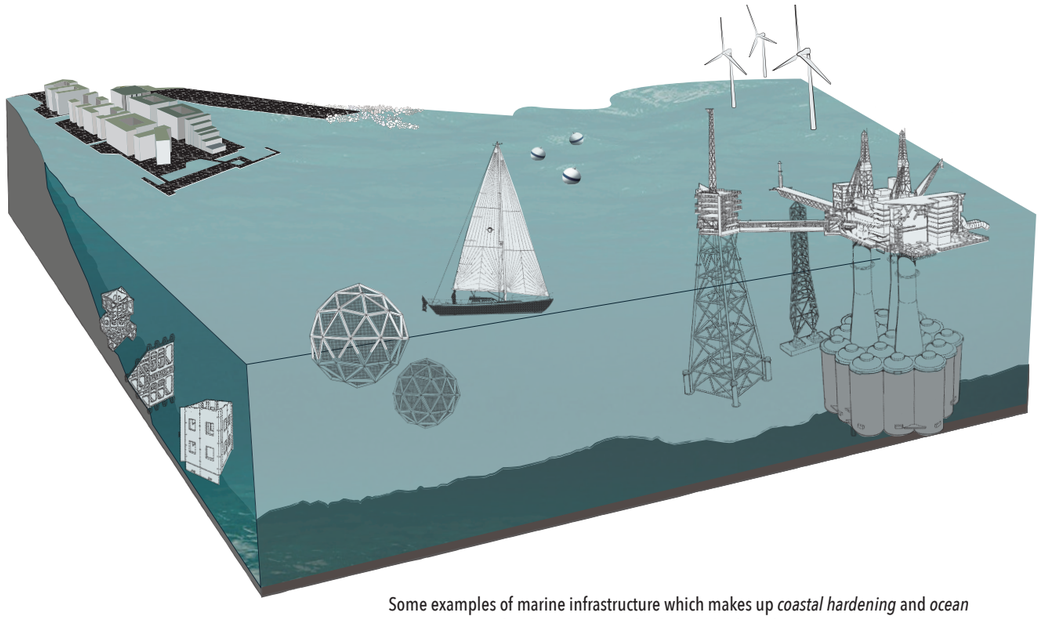
The persistent question throughout this work is how to move from barren urban waterfronts and undersea landscapes to diverse bluescapes: how can the complexity of nature be transferred into an urban context and, thus, help us making more viable transitions between land and sea? By offering a multiplicity of habitats within our built environments, we can, for example, invite marine communities to settle and form liveable undersea metropolises. In this way, the tidalscape's tactile and wonderous world may become an integral part of our world too.

Through the creation of inclusive solutions, this thesis offers concrete ways by which the dynamics of the natural intertidal can be integrated in urban coastal development. Knowledge from coastal ecological engineering forms the theoretical basis of this search to connect the practice of landscape architecture to the sea. Thus, Part II includes an interview with marine ecologist Dr. Louise Firth, one of the world's leading practitioners of innovative nature-based solutions for coastal resilience. Despite the growing body of research within this field, there are still few examples of coastal eco-engineering on a larger spatial scale. My response has been to adopt eco-engineering methods and make suggestions for eco-sensitive designs on a landscape level.

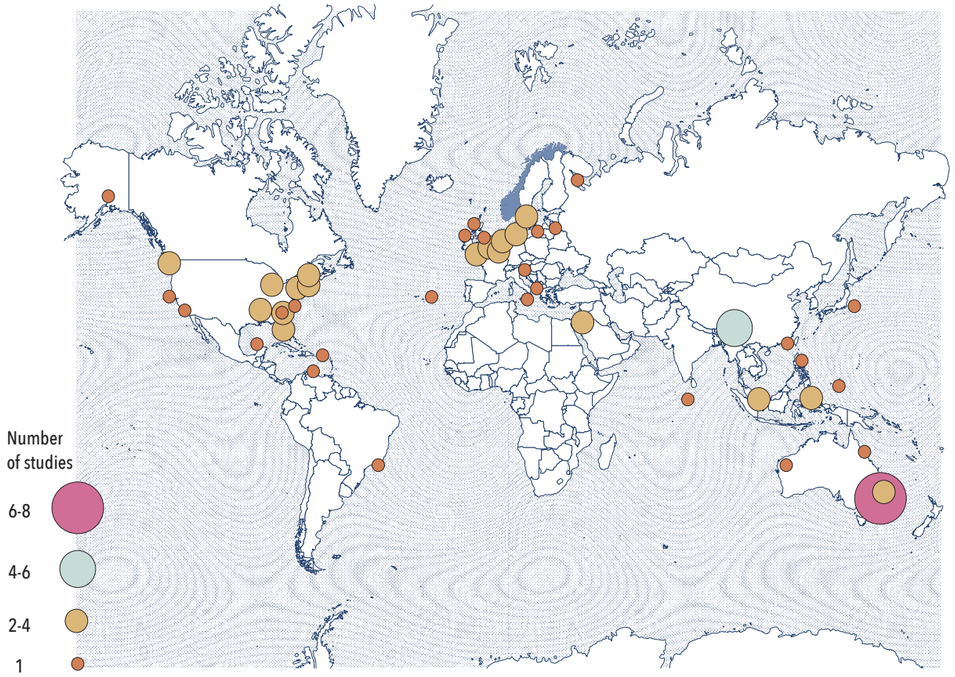
As shown in Part I, the affective source of the study's fieldwork is immersion into the sea by a sense of wonder. In continuation of this, Part II introduces the thesis' practical experiments, which involve embodied engagement with the sea's life-forms, spatial and material qualities. The specific proposals are based on experiencing the tidalscape from kilometre to micrometre by means of lens-aided views on marine life through microscope photography. An overarching concept has been to mirror local habitat diversity in the urban seafront. For example, rock formations from the shore at Frognerstranda and Hovedøya are transferred using a variety of techniques from plaster casting to exploring methods from the field of digital fabrication. The latter is described as a design workflow based on digital manufacturing tools to form various artefacts.[80] Another investigative path has involved the search for marine life-friendly, non-toxic materials for building into the sea. This has led to entering the field of ceramics and developing marine housing by the upcycling of industrial porcelain wreckage from NTP. In this part, the potential of realising urban living laboratories for site-specific trials is presented. The experiences from initiating such attempts has laid the foundation for paper #3, found in Appendix I. The presentation of the thesis' design experiments, many of which were displayed in the exhibition "HAV," can be viewed at RC: https://www.researchcatalogue.net/view/869494/869495 .

The following sections revolve around nature-based solutions, coastal eco-engineering and marine ecology as the learning platforms for arriving at a marine life-friendly landscape architecture.

80 (Formlabs, 2020)



Some examples of marine infrastructure which makes up *coastal hardening* and *ocean sprawl*. Diagram by Elin T. Sørensen © BONO 2020, based on Duarte et al. 2013, p. 95.



Geographical location of a qualitative review of 109 eco-engineering studies. The size of the circles indicates the number of studies at each location. So far there are no such studies in Norway, seen as a blue country. Diagram by Elin T. Sørensen © BONO 2020, based on Strain et al. 2018, p. 431.

"A new physical world is created — the city. However, it is not only a new physical, but also a new ecological, environment."[81]

Re-naturing the urban intertidal

The study's proposed designs for re-naturing the shoreline and undersea landscape are part of a larger trend of international and national efforts to curb the extinction crisis and other environmental threats. At a conference in November 2015, I discovered "Nature-Based Solutions and Re-Naturing Cities"[82] — a report published by the European Union Horizon 2020 program in April the same year. Having worked as an environmental advisor at the Oslo's Agency for Planning and Building Services, I knew the value of international policy initiatives for urban planning and decision-making on a local level. From my next work-experience as a consultant in the private sector, I was also fully aware of the vital role of concrete demo-cases in convincing developers to invest in nature-based solutions. Since we lack adequate reference points for the Norwegian climate and landscape context, I instantly started looking for opportunities to establish a living urban lab as a potential case for the doctoral study. This became the starting point for the thesis' explorative action research covered in Part III.

Nature-based solutions are actions that are supported and inspired by or copied from nature. The research and innovation actions of such solutions for achieving coastal resilience comprise of a broad set of goals — some of which are of relevance to re-naturing the inner Oslofjord. These include the improved well-being and urban regeneration of urban sea areas; the establishment of multi-functional nature-based watershed management and ecosystem restoration; the re-establishment and restoration of previous intertidal habitats; the creation of new intertidal habitats through planting saltmarsh or seagrass at appropriate elevations in the tidal frame.[83]

Re-naturing urban environments, by way of merging engineering skills with biology, relates to the field ecological engineering, defined as the design of ecosystems for the mutual benefit of humans and nature. This implies enhancing qualities and functions, and thus, the ecological value of built infrastructure by the integration of ecological, economic, and societal needs.[84] Ecosystem ecologist William Mitsch, an early pioneer in ecological engineering and co-author of a textbook on this theme in 1989,[85] states that this field must build on co-work and the development of a common language. He encourages the establishment of an international dialogue to "establish the scientific basis, limitations and opportunities for ecological engineering."[86] He emphasizes the fields' dependency on non-linear engineering thinking, and the recognition of Mother Nature (self-design) and Father Time (it takes time). Mitsch writes that it is crucial to deploy nature's capacity for self-design in solving the mega-scale ecological problems of our time.[87] "The Renaturation of the River Aire," mentioned in Part I, exemplifies such an approach.

Ocean sprawl and *coastal hardening* are central concepts to *coastal eco-engineering*. Ocean sprawl implies the proliferation of coastal and offshore artificial structures, as shown in the figure below. Throughout the globe, coastlines have become extensively modified by humans — more than 89 percent of the natural shoreline in Monaco and over 60 percent of the coastlines of Singapore, the Netherlands and China. These coastal structures are built to meet the relatively narrow needs of humans, without much consideration given to the habitats they replace and the marine communities they support.[88] Today's challenge is to manage the urbanisation of the sea "with the dual goal of supporting human populations and activities, [while] simultaneously strengthening ecosystem resilience using an ecosystem-based approach."[89]

81 (Breuste, 2011, p. 17)
82 (European Commission, 2015)
83 (European Commission, 2015, pp. 4, 17-18, 39)
84 (Firth et al., 2016, p. 225)
85 (Mitsch & Jørgensen, 1989)
86 (Mitsch, 2012, p. 5)
87 (Mitsch, 2012, p. 11)
88 (Firth et al., 2016, pp. 199, 203, 214)
89 (Firth et al., 2016, p. 189)

Current eco-engineering research demonstrates that small-scale interventions can have a significant positive effect on the biodiversity of artificial shorelines, and hence, promoting coastal resilience on local scales. Ideally, and to obtain the greatest effect, such enhancement methods should be incorporated in coastal infrastructure during the design phase. Retrofitting settlement surfaces to existing structures in order to enhance native biodiversity is also seen as having a huge potential. Such meas-ures can be compared to biotope roofs and green walls on land.[90] However, enhancing marine life in urban sea areas is not a quick fix. Although small-scale eco-engineering experiments demonstrate real promise, some of the leading researchers within the field also state that "there are many limitations and unknowns," which point to the need for an open discussion about the pros and cons of this practice.[91]

The site as laboratory

The urban environment is an ever-shifting mosaic of change — whereby manifold occasions for research and innovation are potentially within reach. In seeking new insights, some of the study's co-creators and I have made several approaches towards setting up living blue-labs. Our focus has been to create habitat diversity that supports local marine communities, conceptualised as multispecies neighbourhoods which include human costal settlers. The proposals are guided by the spatial qualities of nearby rocky shore formations and local marine nature types of the Oslofjord. The marine nature types that have inspired the designs are shortly presented in Appendix II.

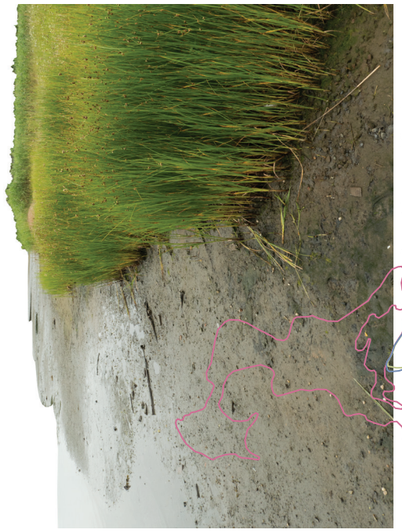
The first living-lab activities, taking place throughout 2017, concerned facilitating moss-microhabitat establishment along a reopened stream in collaboration with a botanist specialising in mosses. The next initiatives, starting early 2018 and of which some are ongoing, promote novel ways to modify the submerged urbanscape. The suggested designs were adapted for the main remaining renewal sites along the Fjord City. They are developed by a core-group, including marine biologist Eli Rinde, urban developer Anne Beate Hovind and myself, in interaction with diverse stakeholders. To this date, we haven't succeeded in physically realizing the proposed demo-cases. Nevertheless, we have raised awareness of the urban intertidal as a landscape in its own right. Each case has resulted in valuable learning outcomes, having laid the foundation for the framework and toolkit elaborated in paper #3. Here we argue that urban living blue-labs form the basis for a holistic adaptive management of the urban intertidal and provide common learning platforms for a much-needed ocean literacy. A few of the trials are referred to in the section "Re/acting in the Fjord City" in Part III of this thesis; the attempts are briefly summarised in Appendix II.

Bridging ecology and engineering

My awakening to eco-engineering owes to an abandoned industrial property at Tofte, a village in Viken county on the western coast of the inner Oslofjord. This was the arena for an assignment to turn the site from brownfield to an area for recreational and residential use. As the transformation took place at a coastal headland, and due to the sense of shame for having been so ignorant towards seascapes, I decided to approach the task differently than usual: as a contracted landscape architect, I joined forces with an ecologist and a marine biologist and set out on an ecosystem-based approach. During our fieldwork in April 2016 the site appeared as a wasteland with the exception of a black alder (*Alnus glutinosa*) riverine swamp habitat, some large deciduous trees with mistletoe in their canopies, and a colony of early bumblebees (*Bombus pratorum*). By including snorkelling in our investigation to view the condition undersea, we observed patches of eelgrass (*Zostera marina*) as well as Japanese wireweed (*Sargassum muticum*).[92] The property developers were not happy about these finds as eelgrass is considered a vulnerable marine habitat type; Japanese wireweed is an alien species; mistletoe, which only occurs by the Oslofjord, is officially protected in Norway. As such, these species could cause delays in the building permission process.

90 (Strain et al., 2018, p. 427)
91 (Firth et al., 2020, p. 6)
92 (Sørensen & Bjørgaas, 2016; Translated by Elin T. Sørensen)

Shoreline softening



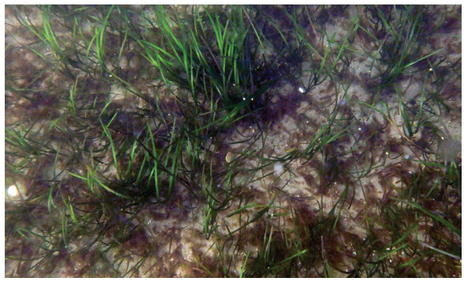
Shoreline hardening





To reach deeper insights into the blue environment and the species we had encountered, I contacted the Norwegian Institute for Water Research (NIVA). Here, we were welcomed by marine biologist Dr. Eli Rinde who introduced us to the works of marine ecologist Dr. Louise Firth. As previously mentioned, Firth is a leading practitioner of coastal eco-engineering currently teaching at the University of Plymouth — also referred to as England's "Ocean City" as it houses several institutions with long marine research traditions. Firth was contacted, and henceforth we received papers on eco-engineering were thoroughly studied. Encouraged by this, the Tofte-masterplan features some of the recommended solutions, for example, a permeable breakwater structure inviting marine life to settle, also conceptualised as a snorkelling and diving site. The local stream was proposed re-opened and directed through the new residential area, with its outlet designed as a brackish lagoon including floating vegetation to purify the water.

The waterscape proposals at Tofte were hard to promote due to the lack of reference projects and experience from similar approaches in Norway. Moreover, the property developer's major concern was to finance the project by devoting the land to residential infrastructure purposes and to an extensive marina; there was little interest in designing on behalf of marine life. Finally, the continuation of the master-planning was assigned to another architect company, and none of the landscaping concepts were taken further. Nevertheless, the stranded brownfield transformation is a major reason for dedicating this doctoral study to the sea. The lack of interest and attention towards the marine environments within the Norwegian urban planning community sparked the desire to engage in ocean literacy. In this respect, the easily accessible fact sheets on eco-engineering made by Firth and her colleagues were inspirational.[93] These, together with the report "Nature-Based Solutions and Re-Naturing Cities," gave encouragement to make urban living labs for advancing evidence-based knowledge of nature-based solutions.[94] However, it became clear that reaching innovative solutions between land and sea would require working in close collaboration with the local marine research community. One first attempt was attending a lecture on dolphins and hydrodynamics by Dr. Karl Inne Ugland (1949-2020), professor of marine zoology at the University of Oslo, in late October 2017. Meeting him shortly afterwards, I was keen to learn about how coastal hardening influences sea currents and water exchange. When introduced to coastal eco-engineering, he enthusiastically proposed to co-write an article for the popular science journal Biolog.[95] This led to interviewing Louise Firth for the same journal — of which an excerpt is provided below.[96] Subsequently, I travelled to Plymouth April 2018, where I met Firth and her students who showed me their test-sites for coastal eco-engineering solutions. The following interview gives a compressed introduction to the state-of-the-art of eco-engineering, as well as to some of the difficulties entailed in this field.





Investigating the sea area by snorkelling at Tofte, discovering a small eelgrass meadow (*Zostera marina*) and encountering a deepnosed pipefish (*Syngnathus typhle*). Underwater photos for the project "Sagene Seil" (Sagene Sails) by Sondre Ski, April 2016.

93 (Bohn et al., 2013a; Bohn et al., 2013b)
94 (European Commission, 2015)
95 (Sørensen et al., 2018)
96 (Sørensen, 2018)

Applying rocky shore ecology to the 'real world'

The questions for Firth grew from my interest in advocating and implementing coastal eco-engineering strategies for the Norwegian context. First an expert on the ecosystems of the rocky shore, and now a renowned specialist on marine enhancement of human-built environments, Firth is an excellent source of information. I was curious to learn how it all started, bridging marine ecology and engineering — what and who inspired her? In the interview, she starts by recounting how her entry into eco-engineering has largely been a random process.

LF From being a Ph.D. student on rocky shore ecology I continued with a post-doctoral position on applied ecology in Florida. To me, this was something new, and I reckoned I would learn a lot. The closest thing I had to rocky shore there was artificial environments, such as piers, pontoons, and bridge pylons. In Florida, I was working on the invasive Asian green mussel (*Perna viridis*), which colonises these hard surfaces. Before this, I had come across Gee Chapman as she gave a talk in Dublin where I was doing my Ph.D. It really got stuck in my head, because her work is taking rocky shore ecology and applying it to the 'real world' and sorting out problems. She told about an experiment, at the time not yet published, describing how they basically worked on the stone blocks in the process of building a new seawall in the Sydney harbour. Rather than armouring the shore, they removed blocks to create cavities and permeability. Also, they mounted a 'lip' — hence, from high tide the water was retained, functioning as a rock pool. I'd never seen something like it before and little did I know at that time that this really was the first of its kind and the beginning of this field; Gee Chapman is the pioneer of 'eco-engineering' in the intertidal environment.

ETS Within the field of landscape architecture and urban planning one must relate to a variety of stakeholders, from local interest groups to the building industry, and often especially the latter are not too interested in marine life. What, in your opinion, is the main reason to be concerned with life below water, and to act?

LF My biggest personal concern right now is the number of people on earth; now, 7.8 billion and continuously trickling up.[97] For thousands and thousands of years, human population has been around. Yet, in the last 300-400 years so much has changed. All of us like to have a high quality of life, and many are drawn to live by the coast — putting a huge pressure on coastal environments. Loads of places I've lived and worked have completely artificial coastlines — and I don't think we can continue acting like this. We need to consider the environment, otherwise we're going to replace most of the natural coastlines with artificial ones. This became particularly important to me from having worked in Malaysia since 2015. In one research project, we looked at the current state of the knowledge and plans for development in the states of Malaysia.[98] Two of them have coastlines, and the government plans are to literally develop the entire coast. This is like what we did in Europe centuries ago; however, I don't think we act on the same scale anymore. Yet in many places, governments still see the environment as something there for the 'taking.' Therefore, working in Malaysia has been an important part of my learning, having increased my conviction that we must pay more attention to the ecosystem and natural environment in general.

ETS Working with the changing of attitude amongst different people, cultures and contexts is a demanding exercise. From my experience, examples from realized projects play an essential role in encouraging and promoting innovative solutions. What is your experience from this?

LF As a landscape architect, you work with developers in Northern Europe. Perceptions are completely different, depending on which way you're looking at something. In my TED-talk, I use a picture of "The Palm Jumeirah" in Dubai.[99] From an engineering perspective, it's an amazing megaproject. It looks beautiful — it is visually stunning — but environmentally it's a disaster. When I practised for the TED-talk, one of the other speakers who is not a biologist or environmental scientist didn't see anything wrong with *The Palm*. From this, I learned to make sure to get my points across on the environmental perspective because different people will look at a concept in different ways.

97 (Worldometers, real-time monitoring)
98 (Yin Cheea et al., 2017)
99 (Firth, 2018)



The Palm is a constructed archipelago in the United Arab Emirates. The construction started in 2001 and is the largest artificial island in the world. The new landscape has increased the Dubai coastline by 130 percent in linear extent. Ecologically, however, it represents a poor habitat. Map retrieved from Google Earth April 2018.

ETS Obviously, we perceive differently — hence the need to 'bridge' and build trust. This motivates my striving for working across disciplines and fields of knowledge. When encouraging new solutions, it is not unusual to meet resistance. Contractors and property developers must naturally be concerned with budgets and timelines. To them, the introduction of structural complexity and variation, together with new materials can seem a both daunting, more costly and hence a risky endeavour. What are your experiences and recommendations related to the 'material world?'

LF Well, here I think marine biologist Dr. Shimrit Perkol-Finkel is probably the best to speak. Her company, ECOncrete, is a pioneer behind the eco-friendly concrete. This is something that I think is really catching on. As far as I'm aware, they were one of first to experiment and publish on it. There are other companies that are emerging, like Reef Design Lab in Sydney[100], developing habitat infrastructure and patenting environmentally friendly concrete mixes. I once had a master student who looked at if some waste materials could replace the cement in concrete mixes, using PFA which is a 'pulverised fly ash,' and GGBS which is 'ground granulated blast slag.' It was a short and preliminary experiment, however, with some neat results: invasive species seemed to have no preference, just settling on all materials. We found that concrete test-tiles with GGBS had a lower richness of native macro-fouling species. However, there were little differences in non-native species richness among treatments. This suggests that materials can alter surface chemistry of concrete and hence, together with more variation in physical features, potentially optimise the ecological value of coastal and marine infrastructure.[101] Reducing the cement obviously has less of an environmental impact and carbon footprint too. I think this is something that warrants more experiments.

ETS The marine biologists and geologists whom I collaborate with suggest that juvenile organisms that prefer hard surfaces have a kind of evolutionary memory when it comes to settlement preferences. To put it very simple — they don't 'feel at home' in the human-built environments that have gradually replaced their natural habitat.[102] What's your experience from larvae settlement on artificial substrates?

LF I haven't done any work on larval ecology, but it would make sense that that's the case. Regarding the material side of things, I'm involved in two other projects – amongst others in cooperation with a chemist, looking at the leaching of heavy metals from the different concrete mixes. It seems that the GGBS leaked a lot more zinc, which is a biocide that basically kills life. It's often used in painting the bottom of boats to prevent them from being biofouled. There is also 'The Singapore Seawall Project,' led by Dr. Peter Todd and Dr. Lynette Loke. They have included me and a master student to study lowering pH in concrete and seeing how that affects the colonising biota.

ETS I've tried discussing the pH-question with concrete-engineers in Norway. In general, they emphasise technical aspects to concrete constructions such as load bearing, etc. Thus, it is useful to have more examples to put forth. One of the concrete engineers I have talked to emphasises area surface and variety in form/structure over substrate chemistry.

100 (Reef Design Lab, 2019)
101 (McManus et al., 2017, p. 655)
102 (Nystuen, 2020; Sørensen et al., 2018)

ETS He points out that both leaching (i.e. heavy metals) and pH-levels change over time in the concrete. The reason for a high pH in concrete is to protect the rebar iron from rust. If there is no need for rebar, the pH may be lower. Material technology is a complex matter. As a landscape architect, my role is to suggest the best solution for a specific context. Hence, I find interest in looking at local geotope-features of coastalscapes. Drawing on experiences from your BIOBLOCK[103], could you mention a few success criteria and challenges with innovative eco-engineering?

LF Such breakthroughs depend on the country and the level of expertise. Moreover, how acknowledged your work is and how well-established the research is. When I first started working on the BIOBLOCK — precast habitat-enhancement coastal defence unit — there were very few examples to show to the developers. Gee Chapman's paper was one of the few. I used this to show what went on in Sydney as a way of saying "Hey look, this is possible." Depending on who you're speaking to, they will have different concerns. The engineers are always, of course, worried about the function and integrity of the structure. Whereas councils are worried about health and safety of the public. And the environmental agencies' huge concern would be invasive species. There are different challenges depending on the various stakeholders that are involved. In the beginning, it was me going to them. I have been working on this nearly a decade. Because of the long-time experience, the team composition, and Plymouth University's reputation for expertise in 'ecological engineering, now people are coming to us asking for advice. The power has changed. Today, there is much more work being done globally, so we're able to showcase a lot more examples. In Malaysia, we're currently at a point where this is beginning to turn. By publishing our research from Malaysia we're building up a reputation together with my colleague Dr. Chee Su Yin. Once the research gets out, people will come to her and me for advice. It took a huge amount of investments in the first place — lots and lots of meetings — but eventually it came our way.

ETS Seemingly, there is something about timing. When presenting ideas on eco-engineering measures for Oslo's waterfront these days, I find the developers more open. Maybe this is due to an increase in public and political concern about littering in the oceans?

LF Well, there is also legislation. In the UK, there is national legislation saying that when developing something in the sea and on land, you must consider nature. Since 2016, there is the EU-strategy on 'green infrastructure.' I think it is raising people's awareness about the fact that we know that parks, trees and 'corridors' are important for biodiversity. I think the 'green infrastructure' will also extend to the sea.

ETS In Norway, and in the field of urban planning and architecture, the line between land and sea is not really trespassed. In most masterplans and residential ads, the sea is visualized as an opaque and concealing surface, whilst only marine biologists account for what's underneath. I experience a lack of communication across fields of knowledge, and I argue that we (the architects) must include the urban blue on equal terms as the 'green infrastructure,' as you highlight above. Lastly, can you tell me more about the World Harbour Project?

LF Professor of marine sciences Dr. Peter Steinberg initiated The World Harbour Project (WHP) and pulled this global network together. In 2014 he invited me and my husband and colleague Dr. Antony Knights to get involved. The trend of global networks, where people are doing the same thing globally, make massive datasets possible. Zostera Ecology Network ZEN[104] was the very first one. The WHP relates to the urban applied realm, with 25 partners involved and four working groups. We are very proud to be the only UK-partner involved in three of them, one of which is the doctoral study of environmental science by Ph.D. student Kathryn O'Shaughnessy, through which she has led the field from the experimental perspective here in the UK.[105] The project settlement surfaces were shipped over from Reef Design Lab in Sydney. Our experiment ran for 12 months at two different sites in Plymouth, and at the same time, 21 partners performed the exact same experiment globally. It's the largest experiment I ever have been involved in.

103 (Firth et al., 2014)
104 (Zostera Experimental Network, 2012)
105 (O'Shaughnessy, 2019)

LF This collective effort is an answer to one of the biggest criticisms of eco-engineering — that most of the work is based upon trials that have been done once, for a very short period and at a single location. However, these experiments are expensive, and often sites aren't comparable. Now, the WHP is taking it to a global level. We're asking if eco-engineering is applicable everywhere, and if we get the same results. I guess, most probably not.[106]







Above left: checking a marine biological experiment in Plymouth, part of Kathryn O'Shaughnessy's award-winning Ph.D. project "Green engineering of coastal infrastructure: a design for life," which examines the impact of sea wall design on marine wildlife. Below left: close-up of 3-D printed habitat design tile created by Reef Design Lab for the World Harbor Project. Below right: a small settlement surface mounted to a stone block seawall, part of James Ducker's Master's thesis. Photos by Elin T. Sørensen © BONO 2018.

NOTES

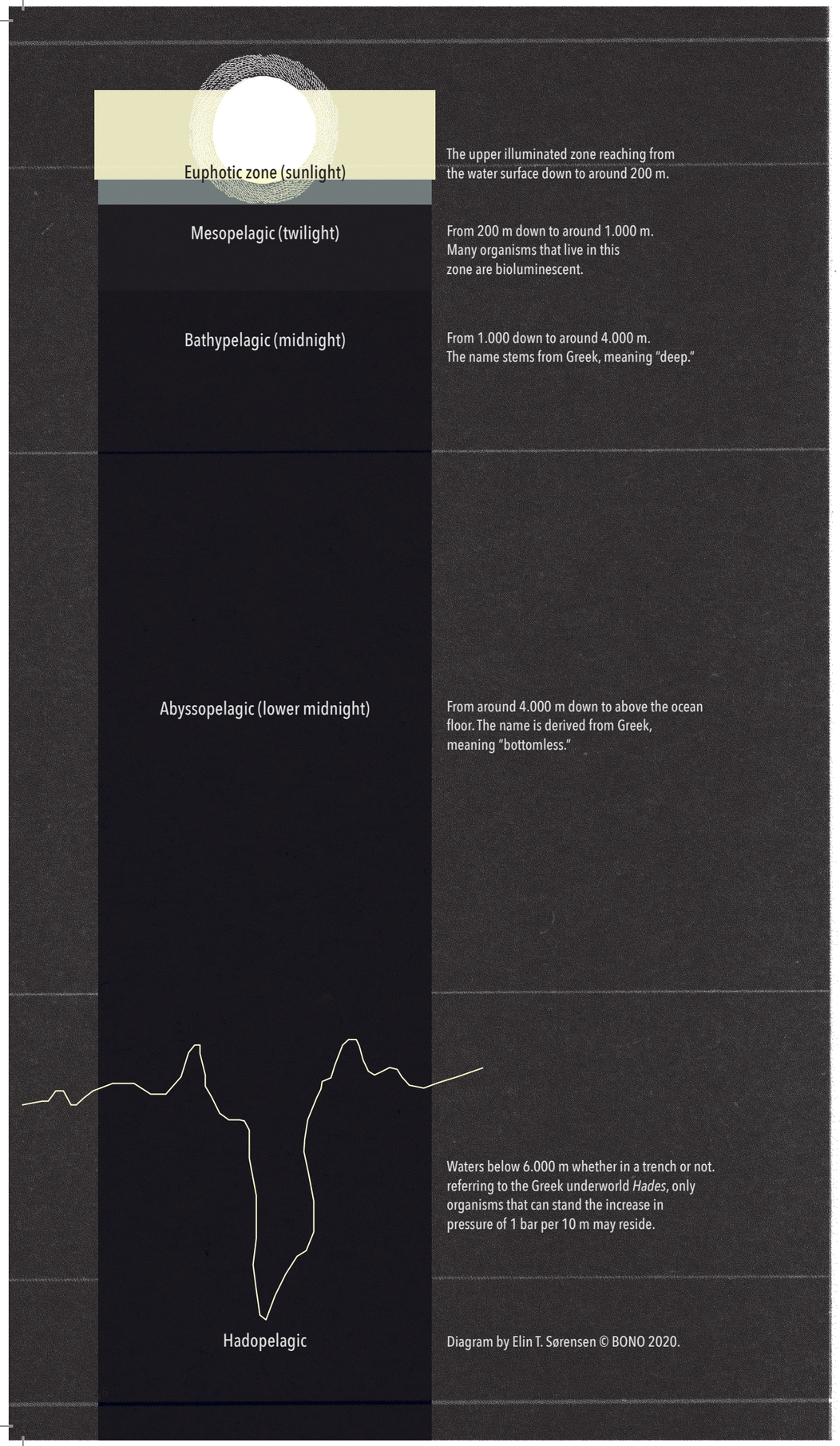
1) TED is a nonpartisan non-profit organization that began in 1984 devoted to spreading ideas, usually in the form of short, powerful talks.

2) Initiated by the Sydney Institute of Marine Science (SIMS), the goal of the World Harbour Project (WHP) is to develop resilient urban ports and harbours through a global network of collaborating scientists. The project brings together international research institutions and agencies concerned with the health of these heavily urbanised waterways and the increasing challenges they face.[107]

106 (Sørensen, 2018, p. 33-36)
107 (The World Harbour Project, 2020)

"In the tide pools, seas in miniature, sponges of the simpler kinds encrust the rocks, each hungrily drawing in through its myriad mouths the nutriment-laden water. Starfishes and sea anemones are common dwellers in such rock-grit pools. Shell-less cousins of the snail, the naked sea slugs are spots of brilliant rose and bronze, spreading arborescent gills to the waters, while the tube worms, architects of the tide pools, fashion their conical dwellings of sand grains, cemented on against another in glistening mosaic."[108]

108 (Carson, 1937, p. 323)



The seashore and its inhabitants

A main entryway to seeking insights from life below water has been the evocative writing of Rachel Carson. Inspired by her, I have made a travel through the intertidal by reviewing literature on marine ecology and coastal eco-engineering practises. Through this study, I have found a necessary basis for contribution to a landscape architecture for the urban intertidal. This has been my way to get to know the seashore and its inhabitants — which belongs to a proposed method for engaging in multispecies co-creation, presented in the third part of this thesis. The below text starts by sharing some features of oceanography, before looking at the habitats of the intertidal and the species interactions that occur there. The last paragraphs address place attachment and the common interests possibly shared between marine creatures and humans.

Layered waters

The water column extends from the water surface to the seafloor. Here some sea creatures must receive light to live, whilst others can do without it.[109] Oceanographers divide the ocean into water columns to describe physical conditions such as light penetration, temperature, salinity, chemical factors such as pH, dissolved oxygen, nutrient concentrations etc., all these being crucial to the sea dwellers. The upper layer is called the euphotic, or "sunlight" zone, defined by the depth where Photosynthetic Available Radiation (PAR) is 1 percent of its surface value. Put more simply, this zone reaches from the surface and extends in clear water down to about 100-200 meters, depending on whether enough light penetrates for photosynthesis to occur.[110] Oppositely, the aphotic, or "midnight" zone, is found in depths below 1.000 meters. Since sunlight cannot reach these depths this realm is bathed in darkness.[111] The deepest known point in the earth's oceans — measuring 10.994 meters below sea level — is the "Challenger Deep" in the Pacific Ocean's Mariana Trench.[112] Humans however, and most marine life, keep to the ultra-thin and light receiving zone. Herein, plankton photosynthesis is responsible for nearly 50 percent of the primary production in the biosphere.[113] Hence, the highest rates of primary production on Earth take place within the interface between land and sea.[114]

Tides

The weather affects waves, wind direction, and air pressure systems — altogether influencing the water level. From desiring to discover and learn from the intertidal, I have eventually developed a close relationship to tide charts for the Oslofjord. As a preparation for each visit along its shore, I had to track the days with the lowest tide.

The Norwegian word for ebb is *fjære* with reference to the device *spring*, both which have to do with the absorption of energy or drifting movements. In Old Norse, fjære points to how the sea "removes itself," as in the part of the beach falling dry at low tide.[115] These names illustrate the movement of very long-period waves traveling through the oceans; waves varying in size through time in response to the gravitational pull of the moon and, to a lesser extent, the sun together with the earth's rotation. Tides are a most reliable phenomenon: "As the sun rises in the east and the stars come out at night, we are confident that the ocean waters will regularly rise and fall along our shores."[116] The tidal range is the vertical distance between the rises and falls, varying from place to place, seasons and time, and also depending upon the coastline shape, geometry and topography of the sea-floor.[117]

109 (NOAA, 2020a)
110 (Merriam-Webster, 2020b)
111 (NOAA, 2020a)
112 (Oskin, 2017)
113 (Field et al., 1998)
114 (Christie et al., 2005, p. 13; Translated by Elin T. Sørensen)
115 (Språkrådet bokmålsordboka, 2020; Translated by Sørensen)
116 (NOAA, 2020b)
117 (Stembridge, 1984)

Undulating interphases between air and water

Up and down the steep shoreface, the wet—dry cycle takes place along a *vertical emersion gradient* within which the rhythmic access to air and water is caused by the action of the tides and weather. The intertidal vertical axis has four physical divisions, each with ecological differences. The *spray zone* is sprinkled by water droplets during very high tides, storms and by high splashing waves. In the *high intertidal zone*, the surface area is flooded during the peaks of daily high tides and left dry in the stretches between the tides. In dry and aired periods, plants and animals living here must withstand extreme heat and drying. This is the home for stress tolerant species such as barnacles, snails, mussels and crabs. The *middle intertidal zone* is submerged and aired twice a day. This is the place for greater variety of plants and animals such as sea stars and anemones. Except at the lowest of spring tides, the *low intertidal* is mostly submerged. Here the water itself affords safer living conditions and life is more abundant. These wet—dry cycles also take place along the undulating shoreline's *horizontal gradient*, influencing both the smallest microhabitats and the aligned shore-habitats seen from a landscape ecological perspective. The changing situations across these gradients determine the rocky shore's communities. Additionally, these surging movements regulate who eats who, and when — mobile organisms seek food at high tide, while shorebirds stroll over the beach at low tide to search for their meals.[118]

The strandline

The strandline is another fascinating tidalscape feature, occurring as a trace of the high-water mark. In my mind's "birds-eye view" I see these debris-formations as the drawings of the ocean. However, these lines of rotting seaweed function as a habitat for many marine species — nowadays suffering from the monstrous masses of human littering. In a beach clean-up event, considered part of the thesis fieldwork at Hovedøya May 4, 2019, the strandline was found to be chock-full of small pellets, also called *mermaid tears*. As the building blocks for most plastic goods, these colourful pellets, between 1–5 mm in size, are easily "mistaken for fish eggs and small prey" by larger sea animals; this food, however, "comes with noxious chemicals."[119]

Blue forests

Algae are a large group of photosynthetic organisms, and in Latin algae simply means "seaweeds."[120] Globally the "blue forests" are amongst the most productive systems on the planet, functioning as natural housing quarters for an abundance of marine species. The blue forests formed by seaweeds, eelgrass and kelp are regarded as key habitats in the highly productive marine environments along the Norwegian coast. For example, on one giant brown alga encountered at a location in Trøndelag, the researchers found over 80.000 associated species. Whilst these three community types share the main habitat-forming features and food chain functions, they thrive under different conditions, attract specific organisms, and are distinctive marine environments that require special attention in managing marine diversity.[121] These three-dimensional bio-systems of foundation species, such as eelgrass on soft bottom or seaweed and kelp on hard surfaces, meet many needs. Henceforth, if you manage to establish them, their associated organisms will most probably settle in by themselves.[122] In the intertidal, these marine plants provide microclimatic buffering, which in turn shields other organisms from large temperature fluctuations, such as high temperatures during the day and low temperature in the night, common in these environments.[123] What is more, the blue forests' inhabitants — like the filtering animals — positively influence water quality.[124]

118 (NOAA, 2020d; UK Marine, 2001)
119 (Gwinnett, 2019)
120 (Etymonline, 2020a)
121 (Christie et al., 2005, pp. 9, 11, 13-14, 16; Translated by Elin T. Sørensen)
122 (Fredriksen, professional dialogue November 7, 2017)
123 (Perkol-Finkel & Sella, 2015, p. 268)
124 (Rinde & Sørensen, 2019)

Marine bioconstruction

In Carson's essay "Undersea" the tube worms cement against one another.[125] This image leads us straight to the phenomenon of *marine bioconstruction* and related processes such as *biological conditioning*, *biogenic build-up*, *bioprotection* and *biofouling*.

Along the shore, some rock types are found to inhibit growth. However, many sessile organisms produce calcareous shells and skeletons through the process of *biomineralisation*, that is, from filtering calcium and carbonate from seawater. By cementing themselves against the surface and one another, these creatures form a secondary layer that lessens the negative influence of quartz and other minerals.[126] Corals, oysters, barnacles, and tube worms are one group amongst the plants, animals and microorganism that act as *bioprotectors*.[127] Today, reduced availability of carbonate in seawater limits their ability to create protective shells, increasing the threat of ocean acidification.[128]

Unlike the roots of plants on land, macro-algae are not dependent on the mineralogy of rocks. Yet, by anchoring themselves to hard surfaces, they *condition the surface biologically* either as a thin biofilm or through larger branched and bushlike plants that provide complex spatial variation. Unsurprisingly, these conditioning processes are considered the "most important factor structuring faunal communities."[129] *Reef builders*, *encrusting species* and *ecosystem engineers* are other names for marine species performing *habitat-forming actions* that either create new habitats, modify, or change the geomorphological and ecological features of the intertidal. Marine eco-engineers may contribute to maintaining or changing the surface properties in ways that benefit later colonists of native species. Or they may completely change the environment they enter and displace the natural community[130] — as when the Pacific oyster (*Crassostrea gigas*) was introduced to Norwegian waters as a delicacy in the 1980s.[131]

Biofouling is also associated with the settlers of substrates submerged in the sea — however, with a more negative overtone. Any natural or artificial structure in seawater is quickly fouled by organic molecules and particles adsorbed onto the surface, and later, by macrofouling species.[132] When the hulls of boats are fouled by organisms, the surface roughness leads to an increase in drag force, which in turn results in higher fuel consumption. These are some arguments why the removal of biofilms and the prevention of their growth concerns marine industries. As mentioned above, marine microorganisms produce chemical compounds, of which some encourage further colonization, while others inhibit settlement.[133] Whilst researchers within the field of eco-engineering seek solutions to enhance marine growth, others pursue the development of biotechnological antifouling strategies. The latter aim for the replacement of antifouling biocides that are toxic to marine life, many of which have been widely banned.



Reef builders from the collection of marine organisms assembled from the shores of the inner Oslofjord, like the tube-building annelids (*Pomatoceros triqueter*). Macro-shots by Elin T. Sørensen © BONO 2020.

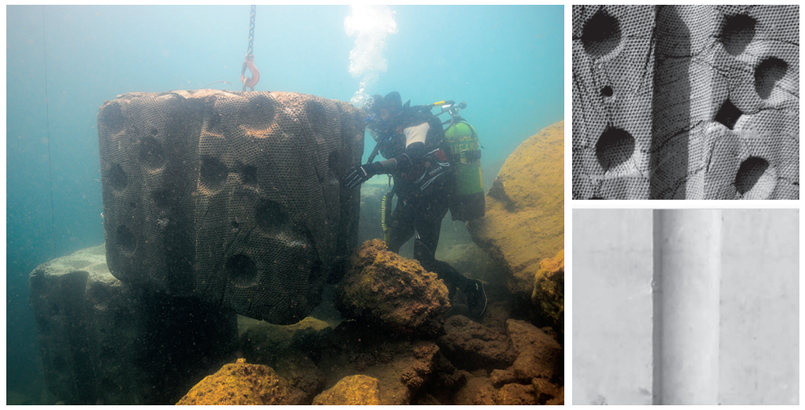
125 (Carson, 1937, p. 323)
126 (Bavestrello et al., 2000, p. 247)
127 (Noffke, 2012)
128 (Fitzer, 2019)
129 (Bavestrello et al., 2000, p. 247)
130 (Romero et al., 2014, p. 2)
131 (Hovden, 2017)
132 (Dobretsov et al., 2013, p. 423)
133 (Dobretsov et al., 2013, p. 426)

Concrete based marine infrastructure

The mineralogy of artificial structures, such as concrete-based marine infrastructure (CMI), is a common topic in coastal eco-engineering, where the abilities of *reef builders* are often highlighted. Civil engineer Jon D. Risinger devoted his Ph.D. study to breakwater structures and marine bioconstruction. Risinger discovered, among other things, that eastern oysters (*Crassotrea virginica*), which cement themselves together, increase the bioconstruction's flexural strength over time. After a period of six months, he found that the oysters added 220 kg to the breakwater, after two years, 610 kg. Risinger argues that this weight and surface complexity contributes to the engineered structure's stability, robustness, and ability to withstand natural forces.

His study also draws attention to concrete additives such as gypsum and fly-ash as having a positive influence on the oysters — suggesting that gypsum may attract oyster settlement. Moreover, the oyster colonies may function as sanctuaries: since the breakwater-oysters are not harvestable, the populations can act as brood stock for adjacent areas that could potentially develop an oyster stock suitable for harvesting.[134]

Similar discoveries have been made by the marine ecologists and founders of ECOncrete Dr. Shimrit Perkol-Finkel and Dr. Ido Sella. In a 24-month monitoring study of a breakwater section in Haifa, Israel, standard breakwater-blocks were compared with three types of ecologically designed prototypes. As shown in the figure below, these prototypes have complex surfaces in contrast to the standard smooth and regular blocks. Moreover, the prototypes were made from a mix of alumina-rich cement blends and silicate-based fly-ash materials. In effect, the ecological units showed lower pH values of around 9-10.5, compared to the industrial blocks made from Portland concrete with a relatively high pH 12.5-13.5. Like Risinger, this research shows how calcite matter released from animals adds strength and structural integrity to concrete installations in the sea. Biogenic build-up acts as a "biological glue" which makes better connections between structural sub-units, not only contributing to added strength and stability but to the longevity of coastal defence structures.[135] Even more, it may lessen the need for maintenance as bioprotection prevents mechanical degradation such as erosion resulting from the grinding of sand or floating debris. Also, reef builders that encapsulate the artificial structures protect the concrete from chloride ion and oxygen penetration, which is a common cause of the deterioration of such structures in marine environments.[136]



Left: ECOncrete® prototypes placed in the sea by a technical diving team. Right: The module's complex surface set against the standard armour-unites cast in Portland cement. Photos by ECOncrete reprinted by permission from Shimrit Perkol-Finkel.

134 (Risinger, 2012, p. 33-34, 125)
135 (Firth et al., 2014; Risinger, 2012)
136 (Perkol-Finkel & Sella, 2015, p. 268)

Attachment to places

The intertidal is the part of the sea that is most accessible to people, a zone used extensively for outdoor activities such as swimming and beach life. The urban intertidal is an assembly of the natural and built environment offering various kinds of social, biological, cultural, economic, and political activities within a living environment.[137] From the above we have learned that the foundation for marine life is severely reduced in this zone by urbanisation of the sea. Here the main limiting factors of human-built environments relate to terrain and growth surface characteristics, light access, nutrients, oxygen, environmental toxins, and other human impacted disturbances.[138]

To maintain biodiversity in general, knowledge of habitat use, animals' mobility patterns and dietary choices is essential. Some basic ecological conditions of the shore and its inhabitants have been introduced above. Now, it is time to look at place attachment and the sense of belonging. This entails developing a close relationship and affinity for a place, including the feelings found in atmospheres of friendliness, such as *at-homeness* and the *freedom to be*.[139] Because of its spatial and sensory richness, I claim that the intertidal triggers such reactions. The term *blue health*, introduced in the last paragraph of this section, provides evidence of this.

Coastal habitat diversity

The intertidal zone exists anywhere the ocean meets land.[140] The geological variations in bedrock, minerals, sediments, landforms and geological processes within a given area are the foundation for all coastal habitats — from rocky shores, sandy and muddy beaches, barriers, spits and sand dunes, to estuaries and lagoons, deltas, wetlands, and coral reefs. Even off the Norwegian coast, there are more than 200.000 cold water coral reefs. Both individually and collectively, coastal habitats offer a greater number of so-called ecosystem services per unit area than other bio-systems — and are evidently highly beneficial to human health and well-being.[141]

As mentioned earlier, the rocky shore is often reshaped by settling organisms through biogenic processes. Together with the *biogenic reefs* formed by marine eco-engineers, kelp forests, eelgrass meadows, and salt marshes are examples of vegetated *biogenic habitats*. *Geogenic* and *biogenic habitats* influence the exposure of coastal communities and potential damage from waves and storms by providing natural coastal protection. For example, whereas steep rocky coasts in wave-exposed areas have no protection against the giant waves that can rise in stormy weather, long beach slopes and irregular surfaces of boulders, mussel or oyster beds absorb and slow wave energy:[142] Compared to analogous hard-bottom habitats in nature, human-built structures are more physically homogeneous at both a micro and macro scale.[143] One effect is that the intertidal zone is compressed. For example, a straight vertical waterfront reduces the surface area to a few meters compared to a sloping beach that may extend hundreds of meters.

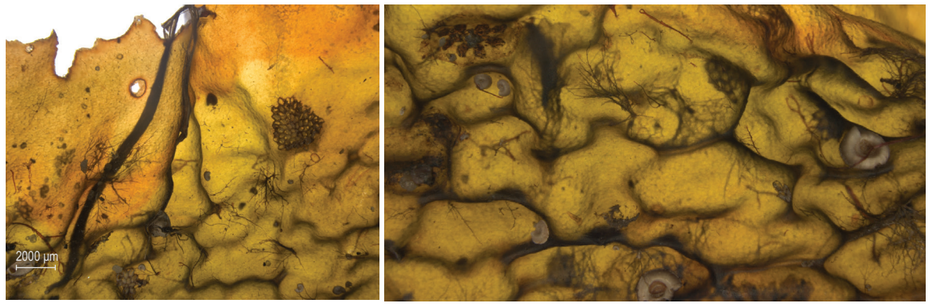
Behaving within marine residential areas

The littoral housing complexes of the sea spread out above, below and in-between the folding architecture of the intertidal. These dynamic marine neighbourhoods have spatial qualities with many similarities to the shelter's humans make, including rooms of different scales and functions, daylight design, energy saving measures and more. In marine research, the term habitat architecture also refers to the number, size, shape, and arrangement of livable spaces for a given organism.[144]

137 (Tiwari et al., 2015, p. 153)
138 (Eli Rinde et al., 2019b)
139 (Seamon, 1979/2016)
140 (NOAA, 2020d)
141 (Amundsen, 2020; Firth et al., 2016, p. 190-191)
142 (Firth et al., 2016, p. 193-194)
143 (Firth et al., 2016, p. 214)
144 (Hacker & Steneck, 1990, p. 2270)

As for the *benthos* or *benthic communities* — i.e. plants and animals that live on the seafloor — some prefer soft sediments, even burying themselves into the mud, whilst others settle on top of or bore into rocks and other hard surfaces.[145] For these creatures, all angles and irregularities grant multi-use spaces: cracks and crevices give safe areas; porous rocks and pools retain water and trap air, providing living spaces to breathe or to stay wet. Hard-bottom creatures choose to settle on top of boulders, whilst small soft bottom dwellers can be found in silt like carpets between and under the beach rocks. In dark places, nocturnal invertebrates may linger during daytime.[146]

Human multi-story structures are between 35–100 meters tall, with up to 40 floors.[147] In the marine megalopolises, a kelp plant thallus or body may stand three meters tall, and a kelp forest patch may include about 10 individuals per square meter. Eelgrass communities can have a density of 100 plants per m^2 with leaves that can grow more than one meter long. These blue forests make up three-dimensional bio-systems, where smaller creatures can attach themselves to the larger plants' root and stem and in turn provide housing and nutrition to others. I imagine the blue forests as living Multi-Dwelling Units (MDU). The alga undergrowth is the ground floor and the small algae, or epiphytes, are each a flat that provide living space to others. Within the marine MDUs, small mobile animals use all possible hiding places, and larger specimen swim up, down, and in-between. Snails that assemble on the top floors search for the surface of kelp-blades. Yet, most species prefer the bushy branches at the sheltered bottom floors. Here the crustaceans — such as crabs, lobsters, and shrimp — hide within red alga bushes. At night, they go out hunting for food. Still, none of the inhabitants eat their own home; rather they live off the cornucopia from their productive community. In addition, the kelp protects themselves against hungry residents by producing grazing-inhibitors. From the rooftops, the seabirds benefit from the green aliment.[148] Functioning as shelter, nursery, graveyard, local food source etc., these marine residential areas represent the lifetime home standard of the sea.



A blade of sugar kelp with folds and textures providing strength and durability, like the ridges of corrugated cardboard. Sugar kelp and other kelps are photosynthetic and use their blades to collect and absorb sunlight near the ocean surface. Micrographs acquired at the Imaging Centre NMBU with Axio Zoom.V16 by Elin T. Sørensen © BONO 2019.

Each sea dweller has their specialized ways to cope. Some figure out how to breath at low tide, whilst others close themselves up. Snails squeeze their muscular "foot" onto rocks, always ready to hide within their calcified fortress to which they are physically attached. To access light, many seaweeds have gas-filled bladders keeping them close to the water surface. Kelp cling to the substrate with a holdfast at the basis of their stem, resembling fingers on a hand. Mussels spin highly flexible attachment fibres, known as byssus threads, to stay on the floor. Starfish take in oxygen from the water from small "valves" all over their bodies. They move along by their many arms, which are regenerative and equipped with hundreds of tube feet. As hunters they wrap themselves tightly around their prey and push their stomach out of the mouth to devour their meal. Sea anemones crowd together to keep moist. Despite their astonishing beauty, they are lethal too: when small fish swim against their tentacles, the anemones release a paralyzing poison and draw the helpless creatures into their central mouths.[149] Wonders never cease to occur in the real world.

145 (Desonie, 2020; Holland et al., 1987)
146 (NOAA, 2020d; UK Marine, 2001)
147 (Emporis Standards, 2020)
148 (Christie et al., 2005, p. 9-12; Translated by Elin T. Sørensen)
149 (Holthe, 2016; NOAA, 2020d)



Sea anemones at The National Marine Aquarium in Plymouth. Photo by Elin T. Sørensen © BONO 2018.

To flow, to bore, to settle

The *sessile* sea creatures depend on anchoring themselves to a surface. Nevertheless, many of them start out as free swimmers before settling and metamorphosing into adult forms. In this life stage, the larvae can recognize different textures by sensory organs mediating sensations of touch and can even orient themselves after chemical signals from the substrate and the surrounding benthic community. Knowledge of the interactions between organisms and minerals is the domain of *biomineralogy*.[150] One example of how the organisms go to work is the clinoid sponge, which produces carbonic acid to dissolve and bore into calcium-containing substances such as limestone or shells. Mussels are another, which bore into limestone with the help of self-produced sulphuric acid.[151] The chemical properties of rocks, like alkalinity, also play a role. Quartz-rich environments, which are studied in several experiments on hard bottom communities in the Mediterranean, are found to limit marine life. One reason may be the oxidising properties of quartz' crystal surface. In a different study looking at the rich variety of sandstone, serpentinite, gabbro, and basalt by the Ligurian Sea, the researchers observed that organisms within the same community group developed different compositions and structures on these four rock types. Minerals released from rocks together with the species interaction are found to play a vital role for marine communities during several life stages. Hence, rock mineralogy and composition are important topics to address in facilitating for the benthos[152] — not least of all in the creation of new marine housing opportunities in the urban intertidal.

Apartment layouts of millimetre scale

Regarding mineral grains and surface roughness, marine creatures respond to textures that fit their body-size. A review of 109 cases shows that the eco-engineering techniques offering the best results are those where the organisms "body size most closely matched the dimensions of the resulting intervention."[153] Another experiment involving acorn barnacles (*Semibalanus balanoides*), demonstrates that in the barnacles' last larval stage before adulthood, they seemed to prefer textures corresponding to their body size of about 0.5–2 mm. The presumed explanation is that these miniscule irregularities protect them both against predation and strong water movements that could otherwise have led the larvae to unwanted areas. Similar choices are observed amongst the tiny larvae of blue mussels (*Mytilus edulis*) and the wrinkled rock-borer (*Hiatella arctica*), which are attracted by fine-scale textures at a millimetre level.[154] Yet another study on barnacles confirms that surface diverseness at a millimetre scale is beneficial to recruitment. Also, the barnacle communities condition the surfaces with more complex habitats for later colonists. In this study, fine-scale microhabitats are promoted to possibly kick-start the development of more complex and diverse macrobenthic assemblages.[155]

150 (Cattaneo-Vietti et al., 2005, p. 65)
151 (Bavestrello et al., 2000, p. 242)
152 (Bavestrello et al., 2000; Cattaneo-Vietti et al., 2005, p. 75)
153 (Strain et al., 2018, p. 426)
154 (Sørensen et al., 2018, p. 25)
155 (Coombes et al., 2015)

Daylight conditions and aeration

Indoor climate and daylight conditions are essential to good architecture. For the sea dwellers, this can be likened to water flow and clarity. Waves and currents are major factors in ocean ecosystems that influence the circulation, settlement patterns and hence richness of marine life,[156] both being crucial to a fresh and clean water environment. On land, architects speak of how natural light nourishes our built spaces and highly impacts people's lives. When creating building complexes for humans, great efforts are made to configure these spaces in relation to natural light and aeration. The building industry offers many tools, such as virtual reality simulators and predictive software, which help architects quantify and qualify light-and other environmental conditions.[157]

Light is similarly vital to many marine organisms, especially the ones that depend upon photosynthesis. One of the previously mentioned examples of large-scale eco-engineering is the Elliott Bay Seawall Project in Seattle. Here one distinct feature is the light-penetrating glass panels integrated in the sidewalks, demonstrating an innovative light-solution for life below water. The design is based upon more than 35 options and simulated light penetration levels with 3ds Max software.[158] This solution has inspired this thesis' 3-D works, such as the floating dock with windows inspired by the configuration of Bryozoa colonies. With respect to improving water flow in Oslo's inner harbour basin, Oceanographer Andrè Staalstrøm at NIVA has introduced a simple way to improve water exchange and increase oxygen levels on a large spatial scale by pumping fresh seawater down to the bottom of the basin threshold.[159] As a reference, an artificial air-mixer has been installed at the Sandon Docks in Liverpool, by which the water improvement resulted in the establishment of a diverse marine community.[160]

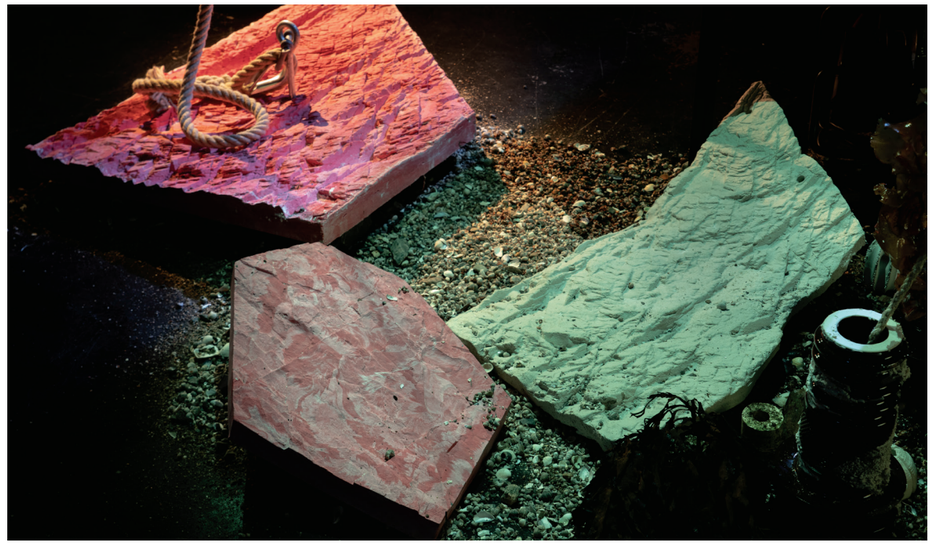
Colour and survivorship

Through my underwater fieldwork, I have discovered the rich colour variations undersea, such as encrusting coralline red algae colouring the bedrock and boulders pink. Yet within the literature, I have only found a few examples of research on marine creatures' colour preferences. My first encounter with his theme was a TED talk by Dr. Kristen Marhaver, who is a coral reef scientist and a voice for smarter ocean conservation.[161] She showed 3-D printed tiles from an experiment that revealed surface and colour preferences amongst brooding coral species. I contacted her in February 2018 for more information on the role of colour, and the following provides some clues to this topic.

During the autumn of 2005, marine biologists Khaled Abdelsalam and Ahmed Abdelhalim tested the succession of marine fouling communities on white, yellow, light blue, red, dark green and black acrylic test-panels. They found colours to play a role to the initial settlers; however, after some months, the colour disappeared as result of biogenic build-up that eventually overgrew the test-panels.[162] In another study on colour and survivorship the two species mustard hill coral (*Porites astreoides*) and elkhorn coral (*Acropora palmata*) were offered a range of colour choices. In this experiment the both corals showed a higher settlement response to red and orange, than to green or white. The ability of juvenile corals to detect colour is seen as an important factor in facilitating survival for coral settlers and, hence, informative to the practice of coral reef restoration.[163] The last colour example is from Christopher M. White's master thesis on the 3-D printed tiles. In order to support the settlement of golfball coral (*Favia fragum*) and low-life lettuce coral (*Agaricia humilis*), White created tiles with surface complexity on both sides in the colours red, white and black. In the experiment, the both species showed preferences for white tiles, whereas *A. humilis* also attached to red and black. The natural habitat of these species includes sand, rubble, and solid limestone, and the coral larvae seem conditioned to use colours as indicators in seeking habitats where they are prone to survive.[164]

156 (NOAA, 2013)
157 (Franco, 2019)
158 (The American Society of Landscape Architects ASLA, 2017)
159 (Eli Rinde et al., 2019b, pp. 15, 28-29; Translated by Elin T. Sørensen)
160 (Bohn et al., 2013b, p. 4)
161 (Marhaver, 2015)
162 (Abdelsalam & Abdelhalim, 2008, p. 138)
163 (Mason et al., 2011, pp. 668, 670-671)
164 (White, 2014, p. 4)

Regarding artificial reef restoration, White puts forth a couple of goals: first to identify the surfaces preferences of the targeted marine organisms; next to get to know the interactions of reef biota with the given surface texture and orientation within the natural environment. The choice of artificial surface should reflect the textures, colours, chemistry of natural habitats and how organisms adapt to their surroundings in regard to shelter, light and shading, spatial configurations and stability.[165] Again we learn that effective nature-based designs depends on knowing the local species ecology.



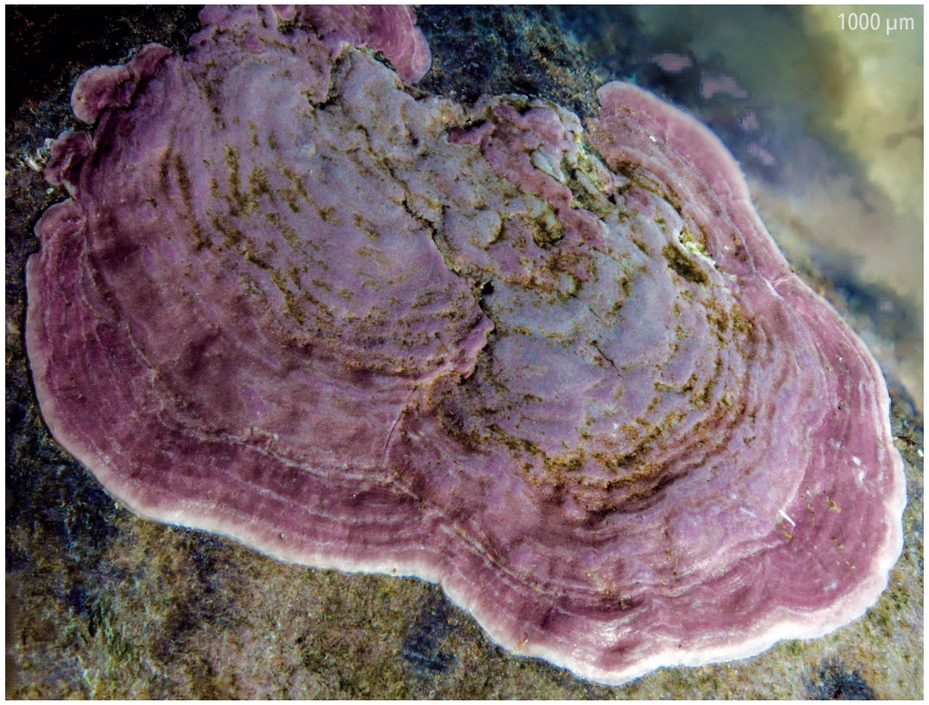
Cambro-Silurian imprints from Frognerstranda: cast in marine life-friendly Jesmonite marbled with red and white pigments. The pink colour is inspired by maerl, and the slabs have beach stones, snail houses and shells underneath. Imprint and casting by gypsum-maker Jean Waldemar Hoff. Marine biological guidance by Eli Rinde (NIVA). Photo documentation from "HAV" by Jon Gorospe. Sørensen © BONO 2020–on going.

Blue health

Personally, I never get enough of seascapes. In my imagination, the patterns created by white shiny barnacles, periwinkles and seaweed are like the jewellery of the shore. I have strong memories of my little son in a hypnotizing interplay with these treasures; the "skree skree-e" of seagulls; the cascading ripples against the shore, continuously giving the feeling that the ocean washes away anger, fear and frustration. And then, all the tiny creatures inside their shells and the blue forests — each single specimen a representative of life. Being at the shore is comforting: honestly, it is the only place where I feel free and at ease.

Humans' connection to the ocean reaches far back to our ancient distant past. Yet today, a deeper relation to the coastscape is seemingly lost. The BlueHealth Project, led by environmental psychologist Mathew White at the University of Exeter in England, is a comprehensive pan-European survey investigating the links between environment, climate and health — and how people use their blue surroundings. For example, the BlueHealth Survey includes responses from over 18.000 people across eighteen countries.[166] In a newspaper interview, White states that waterscapes have a psychologically restorative effect. Compared to staying within green spaces, spending time in and around water shows significantly higher health benefits, such as positive mood and stress reduction. One reason for this, he explains, is that awareness of the present moment has been found to be a key element in stress reduction and overall happiness. Through water activities and by immersing ourselves in water, all our senses are intensely focused on the qualities of the environment. By entering the forceful places of the oceanscape you can "tune into nature like the movements of wind and water."[167]

165 (White, 2014, pp. 16, 18-19)
166 (BlueHealth, 2020)
167 (Hunt, 2019)





Above: blue mussel habited by crustose calcareous red algae. Micrograph acquired at the Imaging Centre NMBU with Axio Zoom.V16 by Elin T. Sørensen © BONO 2019. Below: maerl bed at Krøttøya in Harstad, Troms. Underwater photo reprinted by permission from Eli Rinde (NIVA).

Marine nature types of the Oslofjord

The spatial qualities and species interaction of local marine nature have been the role models for the thesis' marine landscaping. Both the European Commission Environment Directorate and the Norwegian Environment Agency have identified habitats of special importance to biodiversity. In the Norwegian context, the larger kelp forests, close to shore soft-bottom areas, shell sand areas, eelgrass communities and other seaweed meadows must be offered especially good care. Some of these are endangered, like the sugar kelp forests. Moreover, spawning grounds for fish, oyster and scallop beds are considered as ecological functional areas, implying key areas for particular species and populations that must be protected.168 Despite Norway's marine management areas being larger than its landmass and the Government's high priority towards an ecosystem-based stewardship of the sea, we still lack information about many nature types along Norwegian coast.[169]

A short general list on marine nature types and key areas of relevance for repairing and improving the urban sea areas of the inner Oslofjord is included in Appendix II. One of them, having played a central role in this study's practical work is presented below.

Maerl

This marine nature type is recognized internationally as a unique ecosystem. It is formed by several crustose calcareous red algae such as coralline algae, maerl, and rhodoliths within the order of Corallinales, Hapalidiales and Sporolithales. The algae thrive along the entire Norwegian coast, from the shore down to 30 metre depths. They are visible both as a loose-lying algal gravel and as crust on stones or other algae colouring the seafloor, bedrock and boulders pink. Under good conditions, the coralline gravel grows in layers, with new generations covering the old ones. The in-between spaces create various housing opportunities and, among other things, function as a nursery for crabs, shells and fish. The calcareous red algae need sunlight and can only grow in places where enough light reaches them. Maerl beds develop slowly — even less than 1 mm a year. Also, they bind carbon, hence contributing to the carbon budget like the blue forests. Therefore, marine researchers envision maerl beds to be just as important as kelp forests and eelgrass communities when it comes to maintaining the biodiversity of the Norwegian coast. In other countries, the calcareous algae are harvested for use, such as soil improvement, animal feed, food supplements, medicine, and for filtering water. This use threatens the habitat type. Norway's maerl beds are unique in Europe, and since and maerl is a vital living environment to many marine organisms, we must take good care of them.[170]

In search for a marine landscape architecture

The above is my attempt as a landscape architect to approach the blue realm from the perspective of marine life. With respect to marine landscaping, which must build on the flexibility and multifunctionality of natural systems, I have presented some basic scientific knowledge necessary to work as a marine landscape architect.

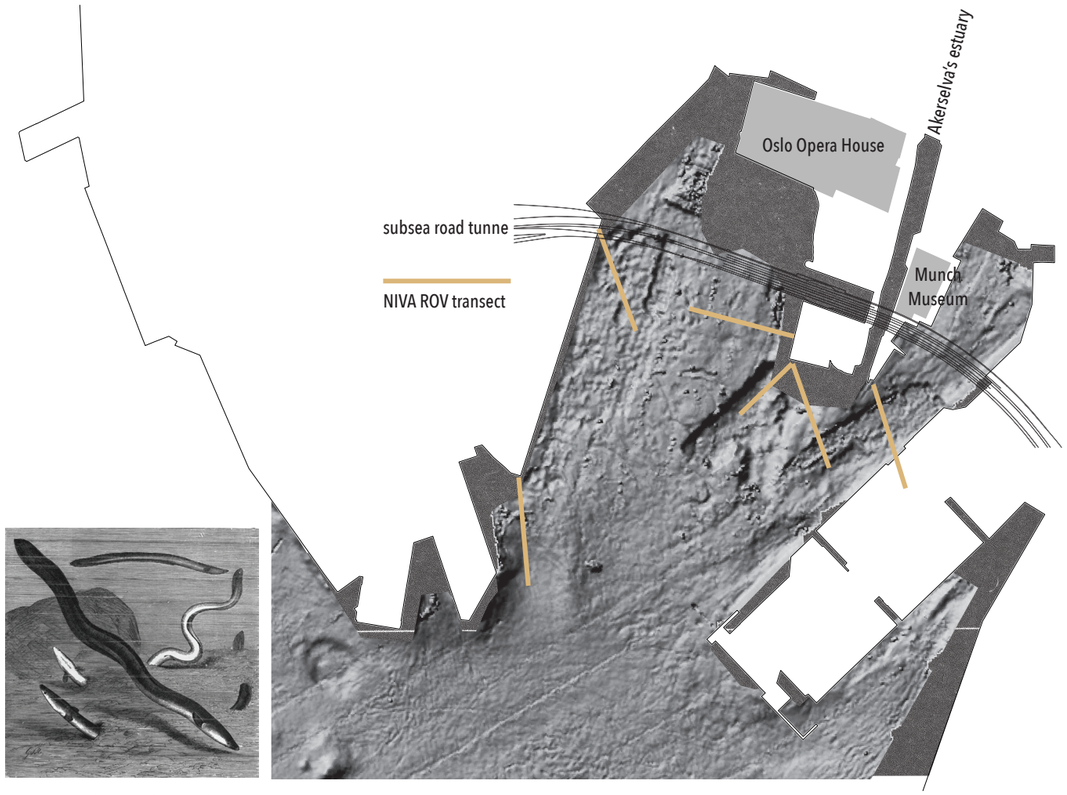
This search for a new branch of landscape architecture has involved diverse methods and techniques — from observing tidalscape morphology and scale and experiencing nature's dynamics to assisting my eyes with the help of microscopes and seeking inspiration from bryozoans. Additionally, the field of digital manufacturing has been explored along with materials friendly to marine life. In the following, some of these lines of inquiry are retold.

168 (European Commission Environment Directorate, 2019; Miljødirektoratet, 2007)
169 (Government.no, 2018; Norwegian Environment Agency, 2018)
170 (Anglès d'Auriac et al., 2019; Omsted, 2018; Rinde, 2018)



100 meters

The Castle Park is 23 hectares.



European eel (*Anguilla anguilla*).

The Bjørvika-bluescape covers 32 hectares.
The shaded relief map shows the latest version from the national database for seafloor elevation data. Due to the interests of National Security, the available resolution for seafloor data has a resolution of 50 by 50 meters, compared to 1 by 1 meter on land. The black space between land and seabed indicates a lack of data input and the six transects show the species mapping explored by NIVA in 2004. Diagram by Elin T. Sørensen © BONO 2019.
Shaded relief map retrieved from "hoydedata.no/LaserInnsyn/," August 2019.

From kilometre to micrometre (µm)

Zooming in and out of maps to get closer or farther view of a location is part of the landscape architect's everyday chores — a daily transition from a bird's-eye view at the masterplan level, to a worm's eye view in order to appreciate the smallest details. Aiming at making space for marine creatures in urban hardscapes, the mastery of the transition from km to micrometre and back has clearly been necessary. When searching in the world of maps, I soon discovered a blind spot regarding what goes on in the zone between land and sea. The desire to fill this gap has hence initiated a long line of inquiry, spanning from landscape connectivity to microcosmoses.

Mind the gap

In most architectural illustrations the fjord appears as an opaque surface reflecting the sky rather than the marine landscape below. As an example of this invisibility, we can look at the bluescape by the Oslo Opera House in Bjørvika in relation to the highly maintained Palace Park surrounding the Royal Palace. Whilst the Palace Park is about 23 hectares, the Bjørvika-bluescape covers 32 ha. The last detailed seafloor inventory of this area was done by NIVA in 2004, as part of the impact assessment for planning of the subsea road tunnel across the inner harbour basin. NIVA found the marine creatures living there to be mainly compose of pollution tolerant species.[171] Let us imagine the Palace Park as a grey mud hole in the capital city centre, only liveable for pollution tolerant species. Nevertheless, the mud had its surprises, and one was the discovery of several burrows on the seafloor made by the fascinating soft bottom dweller the European eel (*Anguilla anguilla*). To make life better for the marine organisms, such as the eel, we need more local knowledge, both of the terrain and other environmental factors. Clearly, the lack of data between land and sea are important gaps to fill in many places that are nowadays being altered and developed.[172] Regarding landscaping for the urban intertidal, I had to access terrain data and connect the zone between land and sea.

A missing link

Like topographic maps showing the three-dimensional relief of overland terrain in terms of colour, shading or depth contours, bathymetric maps make visible the land that lies underwater. Bathymetry belongs to the science of hydrography's measurement of a water body's physical features, such as shoreline shapes, characteristics of tides, currents, and waves, and the water's chemical properties.[173] The Norwegian Mapping Authority Hydrographic Service offers bathymetric data with various degrees of detail. Inside Norwegian territorial waters, the highest resolution allowed is 50 meters between every sounding included in a dataset. Higher resolution data are classified in accordance with the National Security Act. To access data, you must apply to the Norwegian Mapping Authority Hydrographic Service, which in turn applies to the Norwegian Armed Forces for the security downgrading of requested data. Conducting hydrographic surveys in Norwegian coastal waters also requires permission from the Norwegian Armed Forces.[174]

During our landscape architect education, we don't learn about this process. Hence, without training, navigation within these rules and regulations is bewildering. To access seafloor data, I went through a lengthy back-and-forth dialogue involving marine biologists, geodata-caseworkers, cartographers, caseworkers at the Mapping Authority Hydrographic Service and a captain lieutenant military marine geographer. Bathymetric maps are truly difficult to access for several reasons: developed harbour areas are inaccessible to the multi-beam echosounder survey vessel, and therefore seafloor data of the urban intertidal is poor. Obtaining high-resolution data involves bureaucratic procedures that apply to the entire Norwegian coast. This makes it challenging to deliver well-adapted designs for the urban intertidal.

171 (Walday & Olsgard, 2004)
172 (Rinde & Sørensen, 2019)
173 (NOAA, 2020c)
174 (The Norwegian Mapping Authority Hydrographic Service, 2019)





Above: moss animals (*Bryozoa*) living on sea wrack. Micrograph acquired at the Imaging Centre NMBU with Axio Zoom.V16 by Elin T. Sørensen © BONO 2020. Below: a contour map with one-meter equidistance based on land data, combined with the bathymetric data from the inner Oslofjord that has been made available. Map by Elin T. Sørensen © BONO 2020. Data retrieved from Geonorge NGU and Norge digitalt February 2018.

Experiences from several concrete cases show that this lack of data is especially unfortunate for the sake of adaptive and resilient coastal planning. Even the caseworkers at the Norwegian Mapping Authority Hydrographic Service I talked to consider this a societal challenge. They agree that coastal municipalities, fish farmers and ocean industries would benefit from accessing high-resolution seafloor data. There is a need to influence politicians and raise public awareness on the importance of acquiring knowledge of the underwater terrain. These data are crucial to a site analysis which would address the transition between land and sea in anticipation of a much-needed landscape connectivity for this zone. If you seek information on the seafloor, the Norwegian Mapping Authority Hydrographic Service helps with gaining permission to use security graded data for research and business development purposes in smaller areas.

After a while, I learned that a larger area of the inner Oslofjord seafloor has been downgraded by the Norwegian Armed Forces. Eventually getting the desired seafloor contour intervals of 1 meter, I immediately started connecting the land/sea terrain, only to find that the maps didn't sufficiently describe the spatial qualities I had experienced from being in the tidalscape. This disappointing discovery led on to photogrammetry that enables the recording of highly detailed renderings of landscapes. The involvement with photogrammetry is retold in a section below. But first I must introduce the myriad of intertidal sub-environments you may encounter if you let the natural rocky shore be your mentor.

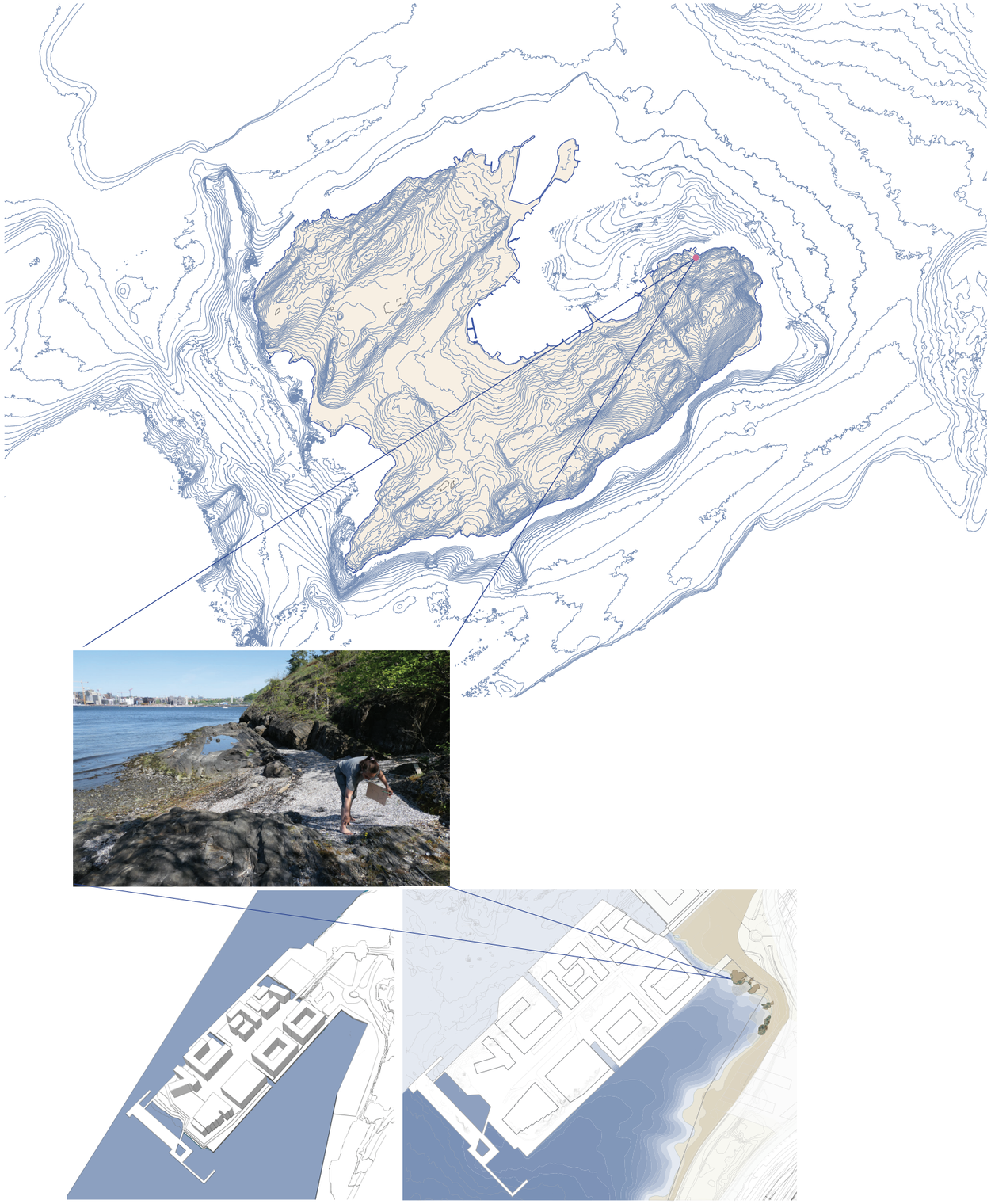
Mirrored landscape

In getting to know the natural seashore as best-practice architecture, the dialogues with my geo-mentor have been indispensable. He has introduced me to the signature landscapes of the Oslofjord, exemplified by the geomorphology of the islands of the fjord such as Hovedøya, Bleikøya, Lindøya, and Rambergøya. These islands, together with the inlets Frognerkilen, Bestumkilen and Fornebu in Bærum represent a Cambro-Siluri-an geological expression. These major divisions of the Paleozoic Era — the Cambrian, Ordovician and Silurian — occur from an interval of geological time that started 541 million years ago and ended 251 million years ago. If we take a closer look at one of these Cambro-Silurian islands, like Hovedøya, its shore landscape comprises both hardbottom and softbottom habitats. Before the costal hardening took place, similar conditions much likely existed along the inner Oslofjord. From these evocative conversations we got the idea of mirroring the Oslofjord's signature landscapes onto the city's artificial shoreline. The creation of new transitions between land and sea analogous to the local geotope's is a key driver for the thesis' practical work. [175]

In the early spring of 2018, I explored the entire shore around Hovedøya. By walking, climbing and wading, I found a small pocket beach at the island's north side with a view towards the city centre. The place touched me. I felt that its spatial and textural universe and proportions were tailor-made for feeling at ease. I owe to this small beach an aha!-moment which entirely changed my perception of the Fjord City landscape scale.

The maps I made from joining bathymetric and land terrain didn't suffice to illustrate the site's spatial richness. Hence my attempts at making more precise visualizations started by measuring the beach with rulers and ropes — and by this learning from direct physical interaction with the tidalscape qualities. Back in front of the PC, I mirrored the refined map onto the base plan of Lohavn. This led to a profound surprise: I could never have grasped the actual scale-properties of the former industrial port had not seen it against this "little beach" offering so much well-being. The beach became a representative of a thriving environment, both to people and marine life, and hence, a guide for site-enhancement of the urban intertidal. Moreover, it made me see how the Fjord City stands as a representative for a bygone era with its remaining industrial scale, both on land and in the sea.

175 (Nystuen & Sørensen, professional dialogues 2017-2020)



Above: Hovedøya's coastline offers 5.8 km of diverse intertidal environments, like the small pocket beach. Photo in the middle: on May 18, 2018, the pocket beach was experienced and measured. Diagrams below: The beach spatiality was mirrored into the industrial landscape in Lohavn, and the seafloor was lifted to a gently sloping beach, as shown in the illustration to the right. An action resulting in an epiphany on landscape scale, diversity and well-being factors. Illustrations by Elin T. Sørensen © BONO 2018/2020.

Simple rules of thumb for the urban intertidal

If you engage with local geotopes, you will encounter the geo-bio-physical processes within landscapes. On the kilometre-scale — and from the bird's eye view — you will find the geophysical conditions. Here the field of landscape ecology expresses the manifold influences on landscape dynamics: nature's patterns, structures and function, and the distribution of ecosystem and habitat patches. The landscape scale represents the highly visible features enveloping the lives of humans and their built environment, whilst the millimetre-scale is the landscape of many marine organisms. This millimetre-centimetre range constitutes the foundation of life for these organisms (as described in the above section). However, in questioning what kind of landscape human activity has left within the urban intertidal, the answer is that there is not much to experience here. In response, the geo-mentor and I have outlined some basic rules of thumb. One essential thing to understand is the specific surface area within the intertidal. The specific surface refers to surface per unit volume or unit length. For example, coral reefs are known for having a high specific surface area per unit. Oppositely, smooth rock formations or concrete structures have low specific surface area. Likewise, it is important to understand that a straight edge affects the environment in some ways, whilst undulating, organic contours have other effects. This goes without discrimination — as each design should be made from what is appropriate in meeting required needs. Nevertheless, enhancing habitat diversity closely relates to increasing the specific surface area. This became evident by the above-mentioned comparison between Lohavn's industrial scale and the beach at Hovedøya.[176]



Left: Ostøya in the inner Oslofjord offers a multitude of ecological niches. If the island is scaled to 20 m^2 it has a coastline of 33.9 m. In comparison, the 20 m^2 artificial island "CPH-Ø1" in Copenhagen has a "coastline" of 16.9 m. It has a uniform design, except from the deciduous tree. Right: texture samples from Hovedøya compared to a concrete wall from Bispevika. As a rule of thumb: the steeper the structure, the smaller the extent of intertidal habitats. The steeper slope with fewer angles and irregularities the less space for marine life. Smooth surfaced and straight edges generally provide fewer living spaces. Diagrams by Elin T. Sørensen © BONO 2019.[177]

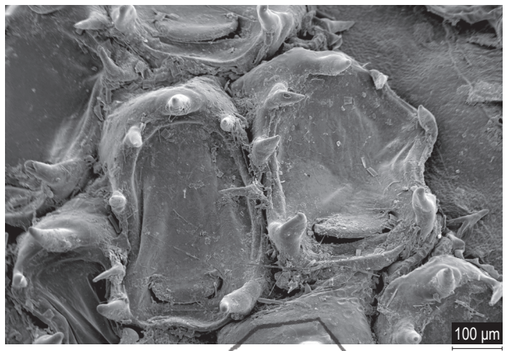
New geological signatures

We have envisioned the creation of nature-replicas, in which natural intertidal textures and chemical properties are also mirrored. From this a few more design principles are drawn: 1) The design must be site-specifically adapted in compliance with local conditions. 2) With diversity in scope, it may be a good idea to mimic the natural shoreline's variation in horizontal and vertical design, as well as its geological substrate diversity. 3) The materials for building into the sea must be non-toxic and friendly to marine creatures. The use of concrete additives with similar chemical properties as local rocks, or the use of local rocks cemented to submerged artificial hardscapes is a theme for exploration. In this way, new geological signatures emerge, offering settlement surfaces like those found along the natural rocky shore. These are principles with transfer value to other coastscapes — for example Hurum on the western coast of the Oslofjord, or Nordland by the Norwegian Sea and above the Arctic Circle, where hard granite and gneisses have different shapes, surfaces and colours.[178]

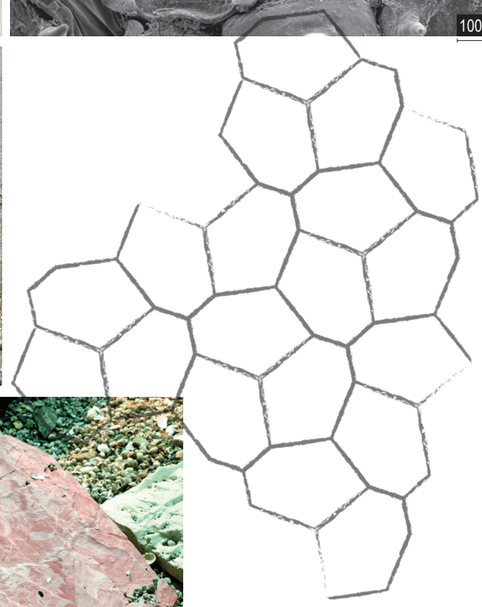
176 (Nystuen & Sørensen, professional dialogues 2017-2020)
177 (Rinde & Sørensen, 2019)
178 (Nystuen & Sørensen, professional dialogues 2017-2020)

To capture local geo-signatures, I made direct small-scale surface imprints in paper and clay. The desire to make larger direct site-specific imprints, which would form the basis of landscape architectural elements for enhancing built structures within the urban bluescape, led to collaborating with the skilled gypsum maker Jean Waldemar Hoff. On May 23, 2018 we spent the day at Frognerstranda making life-size plaster casts of Cambro-Silurian rock formations by the shore. Further design of the slab replica involved creating a modular shape allowing for a variety of pattern configurations. The shapes and patterns for the thesis' different tiles are inspired by moss animals (*Bryozoa*), which can be seen in the microscope image below, together with photos from the process.













Above left: Post-it Note with a key question from 2017: how to transfer textures from the rocky shore and create new landscape designs in marine life-friendly materials? Above right: moss animals (*Bryozoa*) inspiring the pattern configuration for the modular tiles and slabs, which in turn is inspired by the shelving system BUILD created by MOVISI Modular Lightweight Furniture.[179] In the middle left: example of plaster cast from Frognerstranda and the bryozoa-pattern to the right. Below left: the making of imprints from the Cambro-Silurian rock formations at Frognerstranda. These nature-replicas represent local structures at a centimetre-scale and textures at a millimetre-scale. Right: imprint cast in Jesmonite and marbled with red and white pigments. Photos by Elin T. Sørensen © BONO 2017/2018. Scanning electron microscope (SEM) micrograph acquired at the Imaging Centre NMBU by Lene Cecilie Hermansen with Zeiss EVO50 EP. Photo documentation from "HAV" by Jon Gorospe. Sørensen © BONO 2020.

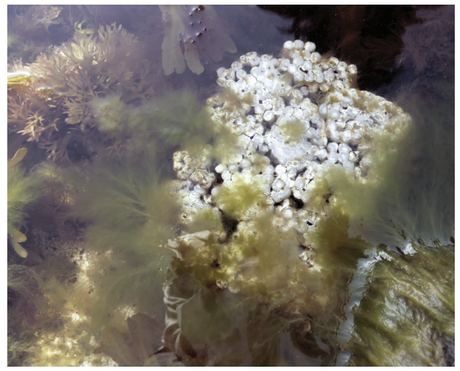
179 (MOVISI, 2020)

Marine life-friendly materials

The above interview with Firth, as well as the previously mentioned work by Perkol-Finkel & Sella, clearly show that involvement with marine life-friendly materials is a multidisciplinary task. Material technology concerns are also one of the main obstacles in some of the living blue-lab initiatives described in Part III and Appendix II.

Early in the process of this thesis, however, a senior advisor on concrete at Unicon — which is one of Norway's leading concrete suppliers — together with my supervisor and me, wrote a proposal to the Norwegian Concrete Association. Our motivation was to develop concrete based prototypes for marine growth trials with anticipated transfer value to larger urban waterfront developments along the Norwegian coast. Unicon's role was to perform analysis of various concrete mixtures regarding additives, chemistry and structural issues. The proposal was rejected, and the initiative was not taken further. Through this, I realized that material technology in marine environments was outside the scope of the study. At the same time, I somehow felt obliged to engage in this matter. Continuing to look for opportunities, my attention was eventually drawn towards ceramic materials. The interest in porcelain and clay owes to their nature-based, non-toxic properties. Following this clue, I contacted a ceramic artist who recommended that I make a visit to Norwegian Technical Porcelain, a manufacturer of ceramic and composite insulators.

Since July 2018, a small-scale experiment involving technical porcelain samples has been carried out undersea at NIVA Research Facility at Solbergstrand. The objective is to observe if and how marine organisms settle on artefacts with different level of complexity. The objects were placed at different water levels in the research facility's 12 concrete basins, which receive a continual supply of seawater from the Oslofjord.[180] Extensive small-scale growth trials have been conducted within the field of eco-engineering. Nevertheless, the experiment gave me the chance to follow the development process of miniscule marine creatures with my own eyes. I discovered how marine life unfolds on different surfaces and shapes, and how the settlements change over time — for example, the development patterns of blue mussel larvae and micro shells, bristles, seaweed seedlings and bullous sackcloth colonies. To me, initially knowing so little of how marine creatures behave, this has been vital. During 2019-2020 the exploration of ceramic materials continued together with Eli Rinde with three week-long working sessions at the factory, re-designing marine housing from industrial porcelain wreckage. The results of these explorations are included in the exhibition "HAV." The growth experiment at Solbergstrand is ongoing, and the new artefacts will be deployed for testing undersea after the exhibition is dismantled.





Left: a porcelain sample placed in the basin at NIVA Research Facility Solbergstrand August 2018. Right: ceramist Tulla Elieson, marine biologist Eli Rinde and artist/landscape architect Elin T. Sørensen discussing ceramic glazes. Photos by Elin T. Sørensen 2018 and Karin Beate Nosterud, NTP January 2020. Rinde/Sørensen © BONO 2020.

180 (The Norwegian Institute for Water Research NIVA, 2020)








Above: photo observations from the growth trials at Solbergstrand showing young sea wrack growing on porcelain in September and October 2018 respectively. Middle: From the work process at Norwegian Technical Porcelain 2019-2020. Below, right: a shrimp in a porcelain house in the saltwater aquarium at the exhibition "HAV." Photos by Karin Beate Nosterud NTP 2020 and Elin T. Sørensen © BONO 2018-2020.

NOTE

In the process of investigating marine friendly materials, I have been in contact with several professionals within the concrete industry: Inventor Per Jahren who made the concrete reefs at Tjuvholmen; The Norwegian Concrete Association Network for Young Engineers (YBN); Professor Dr. Harald Justnes, chief scientist at SINTEF Building and Infrastructure, who conducts researching on how clays can have a new life in concrete in the new product "Eco-cement."[181] Regarding clay based materials, and since Rinde and I are both beginners in the art of ceramics, we have received valuable input from the ceramic artists Tulla Elieson, Eirik Gjedrem, and Ann Beate Tempehlaug. To familiarise with clay, I also had the opportunity to participate in a workshop by the Korean clay artists Hyangjong Oh and Nari Kwon, facilitated by ceramic artist Torbjørn Kvasbø. From building a clay column with a diameter of 60 cm that rose to the ceiling, during a week in May 2019, I gained some direct physical experience with this material.

181 (Justnes, 2016)

Digital fabrication as production method

Highly detailed data was needed in order to represent a unified landscape between land and sea. Additionally, a method had to be found for designing local habitat diversity and reproducing marine landscaping products for potential commercial upscaling with a view to coastal sites with similar challenges. A solution was found in digital fabrication — a design and manufacturing workflow where digital data directly drives manufacturing equipment to form various artefacts. The data may come from Computer-Aided Design (CAD) and be transferred to Computer-Aided Manufacturing software (CAM). The output is data that directs additive and subtractive manufacturing tools such as 3-D printers, which create objects, or CNC milling machines, which cut complex patterns in a variety of materials. A number of such tools exist, from hobby-level to large-scale, specialized industrial equipment including concrete 3-D printing robotics for onsite applications, such as printing new homes.[182]

These technologies represent a revolutionary way to create new architectural designs, worth a doctoral thesis itself. The following section describes only what we have done and what we have learned from attempts at synthesising intertidal ecology and landscape architectural design through techno-based opportunities.

Capturing the intertidal through thousands of images

High-resolution data for marine landscape architecture can be acquired by photogrammetry and Light Detection and Ranging scanning (LiDAR). By using these two techniques, real-world objects and terrain features can be captured from aerial or terrestrial images. The applications for this span from the measuring of coordinates and preparation of topographic maps, to the generation of digital elevation models and aerial photos. LiDAR is a scanning method based upon light-pulsed laser measurement, from which precise, three-dimensional information about the shape of the earth and its surface characteristics can be generated. It has terrestrial, airborne, and mobile applications. Within the field of automated mapping processes and digital terrain models, LiDAR is one of the most accurate remote sensing techniques. The other is terrestrial photogrammetry by means of digital cameras. The term close-range photogrammetry refers to dealing with object distances up to about 200 metres.[183] As alternatives to these techniques, it should be mentioned that many types of 3-D scanners of different qualities exist for generating 3-D models. These, in turn, would provide a third approach that would require another set of tools, software and methods.

The experimentation has entailed efforts to record a Cambro-Silurian landscape at Hovedøya and a granite-geotope at the Nesodden peninsula. The anticipated result was a collection of marine landscaping elements, to be co-developed with 3-D expert Ivar Kjellmo with the support of Ard Innovation. For the LiDAR-experimentation, a geodata supplier company was contacted early in 2019. This company had been mapping landscapes above and below water and fitting the data into a seamless 3-D models for the last 10 years, mostly delivering data for the planning of hydropower dam reservoirs. Their experimentation with mapping marine environments, however, started in 2017. The company was eager to test their equipment for recording undersea, and I was eager to acquire accurate terrain models of the intertidal. One obstacle I encountered, however, was the discrepancy between our respective professional languages. Still, after several meetings during which we tried to reach a mutual understanding on the possibilities and limitations of the technique, it was decided to record at three locations during the lowest possible tide after Easter 2019. Right before the company was ready to begin mapping, the Norwegian Armed Forces put its institutional foot down. As previously mentioned, I had found that a dataset covering a larger area of the inner Oslofjord seafloor had been already released, including the sites of interest. Now we were informed that the downgrading of bathymetric data is done per project, not per location. Furthermore, we were told that all subsea data collection must be approved by the Armed Forces, whether it involved small-scale photogrammetry experiments or multibeam sonar measurement over larger areas. Due to this obstacle, and instead of waiting for the LiDAR data, Kjellmo and I started experimenting with close-range terrestrial photogrammetry.

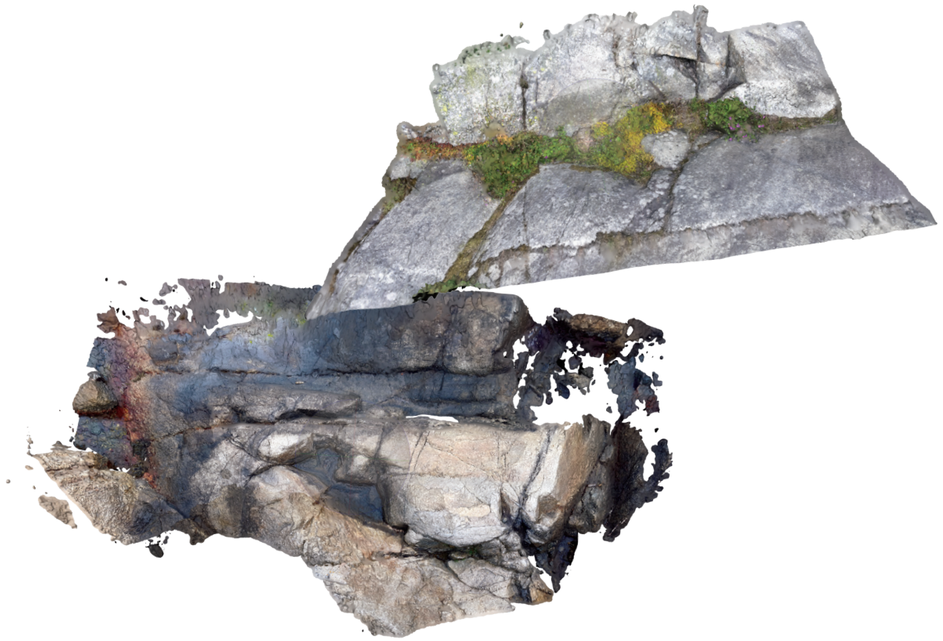
182 (Formlabs, 2020)
183 (Aber et al., 2019; Wood, 2019)







Above: example of the latest high-resolution photogrammetry model with 1.911 of 1.930 aligned images of the tidalscape at Hovedøya. The model can be viewed at Sketchfab: https://skfb.ly/6TSOQ . Below, left: the pocket beach in May 2018. Right: Ivar Kjellmo with a digital single-lens reflex camera, kneed rubber boots and the pink thread at Hovedøya, performing close-range photogrammetry on June 24, 2019. The water level was at 37 cm above LAT between 16.30-21:30 h, with the lowest point at 28 cm around 18 h. Photos by Elin T. Sørensen © BONO 2018-2019.



Examples of photogrammetry from a granite geotope at Sørbystranda with rock pools and the Oslofjord flora. 3-D models with geometry vertex colors generated from point cloud made in *Agisoft Metashape* by Ivar Maalen-Johansen (NMBU), based on Samsung Galaxy S7 shots by Elin T. Sørensen, August 2019. The models can be viewed at Sketchfab: https://skfb.ly/6UWDI and https://skfb.ly/6URD7

Close-range photogrammetry

Our aim was to record site-specific data in order to extract characteristic features of the intertidal, to be refined through 3-D modeling with 3-D printable artefacts as the intended result. The field recordings took place at different times and weather conditions. In the two first attempts at Hovedøya in May and June 2019, we used our Samsung Galaxy smartphones; since the intention was to generate quick test-models, the sites were mapped quite randomly. Parallel to this, I made several recordings of a small patch of vegetation and a rock formation at the Sørby beach with a Samsung Galaxy S7 smartphone. These trials were assisted by Ivar Maalen-Johansen, assistant professor at the Faculty of Science and Technology Geomatics at NMBU. He generated the 3-D models by means of *Agisoft Metashape software*, which is a state-of-the-art photogrammetry tool. In this technique, the alignment of images is crucial. As flowers and grasses comprise a complex structure, it was challenging to match the images and make a coherent model covering the whole scene. Maalen-Johansen and I found that solid surfaces are easier to image-match, as the rock-surfaces seemingly provide a better reference for "gluing" the model together. Presumably, the photogrammetry of vegetation would be more successful if the surrounding rock was more visible in each photo. Having learned this, Kjellmo and I approach the Hovedøya location very systematically at our last photo shoot in June 2019 — this time using a Canon SLR 650D. To assure ourselves of the required photo overlap, we used a bright pink thread as a cross-wise marker in the landscape and shot strips of photos along the thread, being careful not to include it in the images. For each strip with photos from all angels, the thread was moved 50 cm to capture the adjacent surface. We estimated that it would take about two hours to cover the 20 by 10 metre area with around 30 images per section — 800 images in total. Eventually we stayed at the beach for five hours, shooting 1.930 images. The fully textured photogrammetry models are generated in *Agisoft Metashape*.

Recording under a blanket of clouds

It is instructive to compare the results from these different recordings. At the two firsts shoots, we struggled with timing and direct sunlight. Strong sun results in hard directional shadows, unpredictable white-balance conditions and reflections that may interfere with the potential accuracy of the 3-D model. In the case of tidalscapes, and to capture as much terrain as possible, a successful photo session requires extremely low tide. Dry weather is a must, as wet surfaces reflects the light that again comes in the way of the 3-D model optimization. Hence, the ideal is an overcast day, where the landscape appears shadowless under nature's softbox formed by a blanket of clouds.

Owing to a new collaboration involving photogrammetry and marine settlement surfaces, Kjellmo and I have learnt more about this technique from 3-D expert François Bougnères. His company, among other things, renders archaeological sites and iconic artworks from French national museums in photorealistic 3-D. Their success is achieved by 360-degree recordings, with images shot at a new angle every 5 degrees. Their main tools are a Nikon SLR D8 150 for extreme high-resolution photography and the photogrammetry software *Reality Capture*. For efficient photogrammetry-based models of landscape and outdoor scenes, Bougnères recommends a RICOH THETA camera with a timer — a lightweight camera that can record images every 2 seconds. Using this, the photographer can focus on moving around the object and manage all the required angles. A 30 percent overlap between each image is required for best results.[184]

Georeferencing models from different datasets

Our attempted method was to record small geotopes to be integrated into the LiDAR based model covering a larger area. This implied stitching together and combining two datasets based on different geomatics tools — a process we didn't expect to offer any problems.

In airborne mapping, aircraft are equipped with a *Global Positioning System* (GPS). However, in order to derive georeferenced point clouds from photogrammetry-recordings, the data must be identified with its right place in the world.

184 (Bougnères et al., professional dialogues 2020)

From Maalen-Johansen we learnt that in order to succeed in combining datasets, we should have geo-referenced the location. This may be obtained by defining positioned ground control points in advance, for example, by using the corners of a building or other recognizable landscape elements that are easily traced on an aerial map. As a rule of thumb, a minimum of 4-5 control points per model is required. Since we hadn't performed a manual georeferencing and the models had different resolutions, fitting the datasets together meant a good deal of tweaking. To this date, we have not yet succeeded in finding software that can automatically connect different datasets acquired from separate geomatics-techniques. We also have experienced that to enter this field, it is useful to have some insight into the tools and technical possibilities, as well as the different stages in the 3-D production pipeline. As the next paragraph reveals, to order mapping and 3-D products requires a certain expertise in the field.

The airborne green laser pulse scan

For the intertidal mapping, the data supply company used a Teledyne Optech Titan LiDAR apparatus with three laser pulses providing for data measurements on land, and a green channel that penetrates water. Because water absorbs less green light, the green channel enables airborne laser bathymetry in shallow water. In our preparatory meetings, the discussion went back and forth concerning the anticipated quality of data-harvesting. The company's geomatician argued that the green laser could record to a maximum depth of five meters under good conditions. We agreed to map early in spring, before the tree canopies covered the landscape. The main objective being to record as much of the intertidal as possible, I stressed the need to choose a time when the low tide was as far down the beach as it could be.

After eight weeks processing time, permission from the Norwegian Armed Forces operational headquarters was finally granted. The mapping was performed on May 23, 2019 between 08:15 and 08:45 AM. The aircraft altitude was held at 400 meters above ground. In flight, the sea level was 16 cm higher than the absolute low tide occurring at 03:30 AM; during the data collection, the tidal range moved from 7 to 11 cm below standard elevation zero m (NHN). As the geomatician later told, a good aerial photo depends on the sun's height above the horizon being 25 degrees. Therefore, instead of flying at the lowest possible tide, the data-collection started when the solar angle was right for obtaining the model texturizing-photo — which was 08:13 AM on that day. The subsequent confusion was due to the timing. Had the data supplier and I fully understood oneanother, and that the main interest was to acquire the best possible basis for creating intertidal 3-D models, the sites should have been recorded at 03:30 AM.

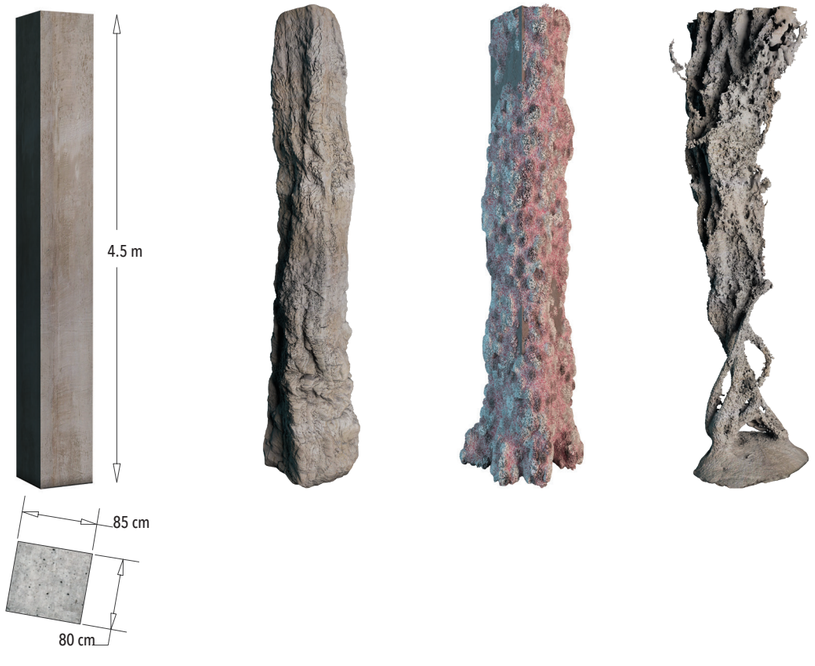
In their final report, written in a highly technical language, they stated that the data processing went flawlessly, highlighting that the desired details, such as the tidal pools, were visible in both the 3-D geometry and texture. Despite the fact that the scanning was performed close to land, he explained that the sudden steepness of the undersea terrain had limited the recording of depth data. In questioning these rather disappointing and even useless results, I got answers that ideally should have been provided before contracting. A main reason for the poor results is the optical characteristics of coastal waters, which are not only determined by water itself, but by suspended particulate matter such as organic detritus and phytoplankton. Heavy rain and flooding are well-known causes of such particle accumulation. Nevertheless, because the concentration of particles in the water column is unpredictable, recording below the water surface much depends on lucky timing. In the final discussion, the geomatician clarified that the green laser pulse only can detect depths down to a maximum of one depth of the Secchi disk, which is a measurement relative to water clarity. This implies that you cannot expect the apparatus to record deeper than you visually can see in an aerial photo. Another limitation to undersea recording is ocean sprawl and the dense covering of the water surface by floating marinas etc.

My expectation was that this state-of-the-art technique would be the best help in obtaining undersea terrain data, which is essential for a sustainable development between land and sea but missing today. What I discovered is that there is a high degree of uncertainty associated with LiDAR. This mode of recording comes at a high cost and involves a bureaucratic application procedure. Hence, photogrammetry of smaller locations seems to provide for the best option for data harvesting. However, there are some issues to be aware of before venturing into this world.

You should have some knowledge of the technology available, its limitations and potential, before deciding on the right technician service and tools for the task. A successful recording is all about timing: light conditions are essential. With photogrammetry, the alignment of images is crucial too, requiring a systematic approach using appropriate recording devices. The creation of detailed 3-D models requires high perfomance computers. Choosing appropriate 3-D rendering software and the computer engine capacity is tightly connected to the project timeline. Stitching together models from two datasets based on different geomatics-tools requires separate software and must be based on georeferenced control points; either a land surveyor must be included in the fieldwork, or else you must perform the referencing manually. From discussions on underwater photogrammetry with a diver and 3-D scanning enthusiast, we have recently learned that successful results require artificial lighting as well as a stationary subject; mobile animals and seaweed will cause disturbances in the images and hence impact the final model. In underwater photogrammetry, 80 percent overlap between each image is currently required in order to capture a motif and create a coherent model. Pending the availability of more advanced technologies, the best alternative is to wait for the lowest low tide.



Left: a creative technologist preparing for 3-D scanning of toothed wrack (*Fucus serratus*) attached to a stone in the making of a marine landscape architecture. Right: model of a sea wrack pillar made as a 3-D printable file. Photo and 3-D model by Ivar Kjellmo 2020.



Left: concrete pillar from the Bispevika development used as a reference for the new designs.
Right: Cambro-Silurian pillar, Maerl pillar and Sea wrack pillar.



Above: floating dock with windows created in modular shapes inspired by the configuration of moss animal colonies.
Middle: a pontoon with a Cambro-Silurian habitat underneath. Below: concrete end of a dock with a Cambro-Silurian face.
3-D visualisations by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020.

A catalogue of marine landscaping elements

Despite the above difficulties, the results from Hovedøya provide excellent example of close-range photogrammetry. We succeeded in creating a large digital landscape model from which we could extract structures and textures. Our initial aim was threefold: First, to create a larger landscape model for revealing the dynamics of the tidalscape — the tidal range, wave impact and so on — possibly expressed using virtual reality, affording a user the experience of immersion and the feeling of being a part of that world. In the course of the experimentation we did not manage this. The second goal of creating building blocks for the collection of marine landscape architecture samples, however, is completed. Thirdly, we envisioned making use of a concrete 3-D printer to realize some designs in a life-size scale. This was not achieved, yet we have succeeded in making small 3-D printed tiles in porcelain.

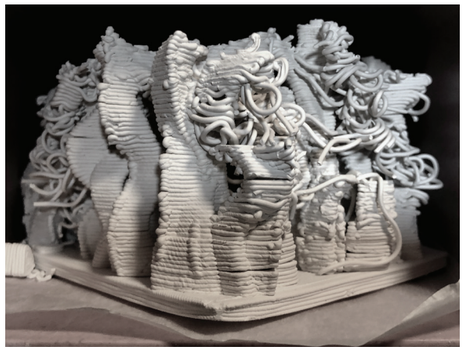
Through the creation process for the marine landscaping elements we have developed different methodological workflows: the 3-D modelling, processing, animation and rendering done using the software *3ds Max*, with *V-Ray* as renderer. Postproduction and editing are performed with *DaVinci Resolve*. The artefacts are for the most part directly linked to the captured photogrammetry models. However, like a photographer needs Photoshop for editing and final tweaks, the 3-D worker needs brushes to fix the geometry; the further refining of the artefacts is done by means of *Zbrush*. This sculpting software allows for extracting a *vector displacement map* of the model that can be used as a "painting brush." Hence, the digital artist can paint selected patches of, for example a site-specific geo-signature, directly on any desired surface of a given model. The two mapping techniques and the extracted products are included in the video "Marine Landscape Architecture," available at RC: https://www.researchcatalogue.net/view/848167/972292 . As seen in the video, most of the objects are given a cement texture in order to highlight the possibility of manufacturing the products. The products are adapted for the submerged hardscape of the Bispevika residential area in Bjørvika, which is presented more closely in Part III. This reference environment's spatial proportions, as well as dimensions for the loadbearing pillars, derive from the project Building Information Modeling (BIM). In the course of the experimentation we have produced three different artificial intertidal "species-" and "geo-signatures."

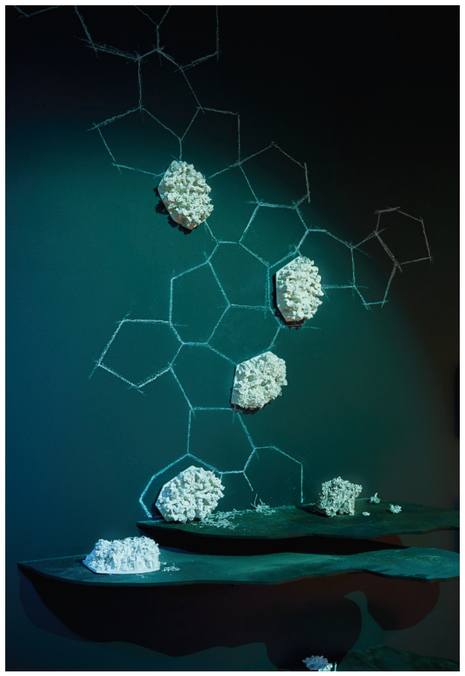
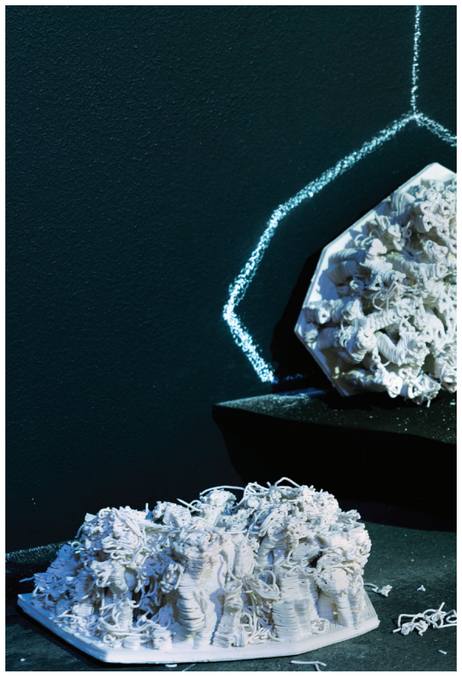
Concept for pillars. So far, we have created one structural and two textural options: For one pillar, Kjellmo has made three different *Zbrush* designs based on the Cambro-Silurian landscape photometrically captured at Hovedøya. Another surface design mimics the marine nature type maerl, introduced above. This model is also based on an artistic approach using procedural noise and displacement maps created in *3ds Max*. The structural example is based on a photogrammetrically recorded toothed wrack (*Fucus serratus*). This design is true to the original model, only slightly adjusted to fit the environment of the Bispevika quarter as a marine loadbearing pillar.

Concept for floating docks. Hitherto we have made two versions of marine friendly floating docks. One offers a three-dimensional habitat underneath the pontoon. In this sample, we sought to replicate the original Cambro-Silurian landscape formation from Hovedøya. The other model has clusters of small windows to let sunlight down to the seafloor. The concept is intended for shallow water situations, where light access would benefit eelgrass plantings. Additionally, this pontoon is equipped with pending ropes for the establishment of hanging marine gardens. This model represents an artistic approach made in *3ds Max*.

Concept for tiles. To date we have fabricated two types of modular 3-D tiles. The tiles are made in *3ds Max* using *Zbrush*. One is modelled after the tube-building annelids (*Spirobranchus triqueter*), the other is inspired by acorn barnacles (*Semibalanus balanoides*). The source for the digital brushes in the latter texture, is an eight-by-five-centimetre stone with barnacle colonies.

Concepts for miniature marine landscapes. For some of the products, a complete structure was cut out of the photogrammetry model. One example is the concrete end of a dock with a new face modelled on nature, another is the miniature landscape under the above-mentioned pontoon. A third example is a larger part of the Hovedøya photogrammetry facilitating a more diverse habitat within the submerged part of the Bispevika residential area. Additionally, we have generated a model showing a potential shoreline formation that mimics the variation of the natural rocky shore. This model utilises local surplus rock material and is designed to facilitate blue forest and marine communities. In this tidalscape we zoom in on some details, among others, ecological functional areas such as boulder habitats for shore crabs (*Carcinus maenas*) and lobsters (*Homarus gammarus*). These visualisations were made on behalf of Bærum municipality and based on a transformation of the location Lakseberget, today a marina situated between European route E18 and Lysakerfjorden in Sandvika.



Above: 3-D tile inspired from the tube-building annelids, and from the firing process for making the ceramic tiles by ceramist Ingjerd Aarseth. The 3-D printing process is documented by a time-lapse video included in the video "Clay works," which can be viewed at RC: https://www.researchcatalogue.net/view/869494/979797 . Below: the porcelain tile in the exhibition "HAV." Photo documentation by Jon Gorospe.

NOTE

3-D printing with clay, porcelain or other fluid-dense materials is an international research theme within additive manufacturing. Large-scale, cement-based additive manufacturing processes, often referred to as 3-D concrete printing (3DCP), have been under development for the last 10 years. Currently, there are several groups worldwide involved in such research, for example at Loughborough University in England, the Danish Technological Institute, the National Institute of Standards and Technology in the USA, and Conservatoire National des Arts et Métiers in France. Current 3DCP manufacturing processes are inconsistent and unreliable, requiring expert machine operators and extraordinary care in the preparation and formulation of materials.[1] "Concrete Choreography" is one 3DCP of inspiration. Here nine individually designed concrete columns are 3-D printed at full height by a teacher and students at the Institute of Technology in Architecture at ETH Zurich. The method they developed allows the production of concrete elements without the need for any formwork. Each column is 2.7 metres tall and was created by fully automated 3-D printing in 2.5 hours at print-speed of 180 mm/sec. The hollow structures were provided with a steel structure in the centre and filled with concrete once the printing process was finished.[2]

1 (Buswell et al., 2018, p. 37-38)
2 (ETH Zürich, 2019)

A new ceramic specimen. The modular 3-D tile inspired by the tube-building annelids was printed in porcelain using a *Delta WASP 2040 PRO printer* at the Oslo School of Architecture and Design. Six copies of the same 3-D model were printed in Limoges porcelain, supplied by WASP. The water and porcelain mixture are hand-combined with 5 percent ethyl alcohol by volume: the alcohol allows extruded porcelain to dry at a faster rate, keeping the lower layers solid as the print proceeds.

The printing time was 8 hours per tile, at printing speed of 180 mm/sec. Porcelain tube layers were 25 mm in diameter. The printing nozzle had a diameter of 0.6 mm and deposited 1 mm layers. To achieve a durable quality, the tiles were fired in a ceramic kiln. These tiles were fired at a temperature of 1230°C, consistent with the requirements for Limoges porcelain. No glaze was applied, as the porous surface is desired, and no additional substances are introduced. STL files for the tiles were processed using the *Cura software* by *Ultimaker* into the required G-code for printing. As Cura is not explicitly configured for clay printing, the settings had to be adjusted based on recommendations from WASP. The parameters were further tweaked through experience with test prints, to account for the environmental conditions the printer was in.

Porcelain printing introduces additional variables to the modified Fused Deposition Modeling (FDM) printing process. The mix of clay, water and ethyl alcohol varies in overall consistency. And fast drying is both a requirement and a detriment, as evaporation causes overall shrinkage but brings necessary rigidity. These additional conditions produce imperfect representations of the digital model. Imperfections are anticipated and harnessed to add organic randomization to the otherwise exact copies. By this, each tile resembles a unique "organism."

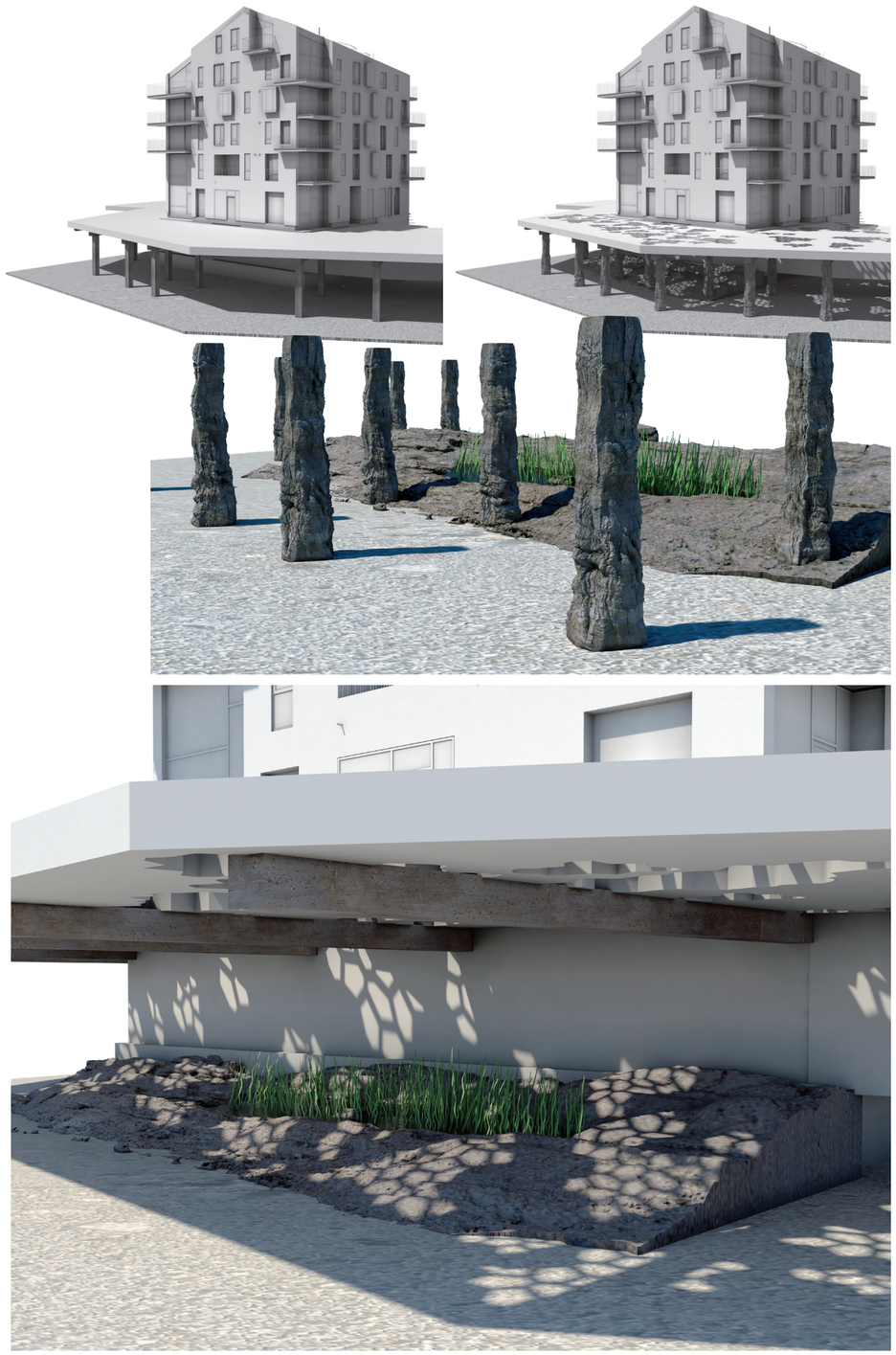
Through our dialogue with Bougnères, we came to understand that the additive manufacturing of large structures is wisely combined with traditional casting techniques. The largest 3-D printer he knows of in France has the capacity to print about 1 by 1 metre. Printing larger sizes may become increasingly expensive, hence, it is advisable to choose the technique most appropriate for the desired result. For example, we found that the creation of smaller modular pieces to compose larger reliefs is a viable option.[185]

The thesis' experimentation demonstrates some opportunities and limitations with digital fabrication. We have not yet succeeded in recording high resolution undersea landscapes. This represents a future challenge together with further refinement in the collection of marine landscape architectural elements.

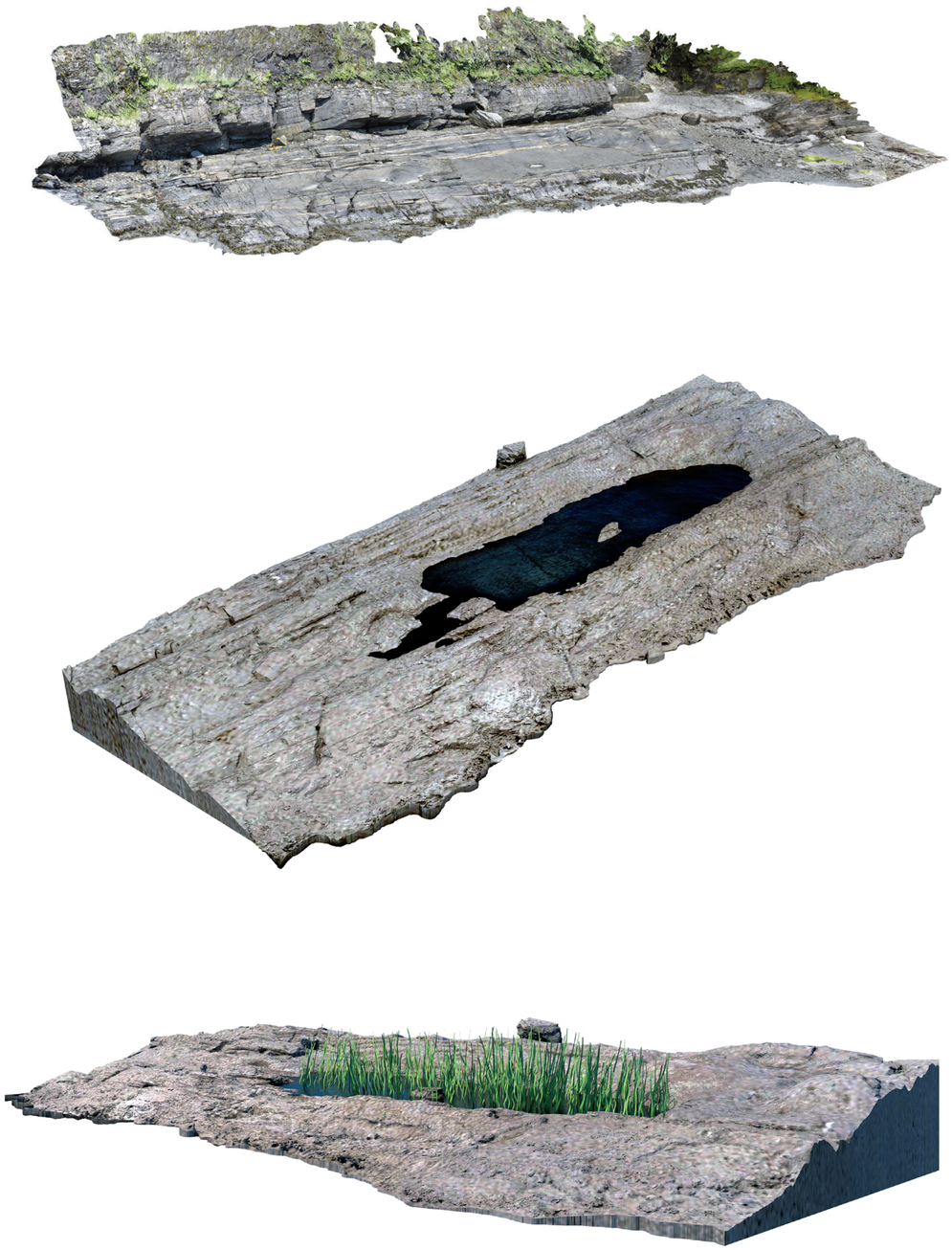


Left: Samsung Galaxy S6 image of the original barnacle colony from Nesodden, and the photogrammetry model based on the mobile shots in the middle. Right: micro-landscape with acorn barnacle colonies as the basis for 3-D tiles, modelled and 3-D test-printed by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020.

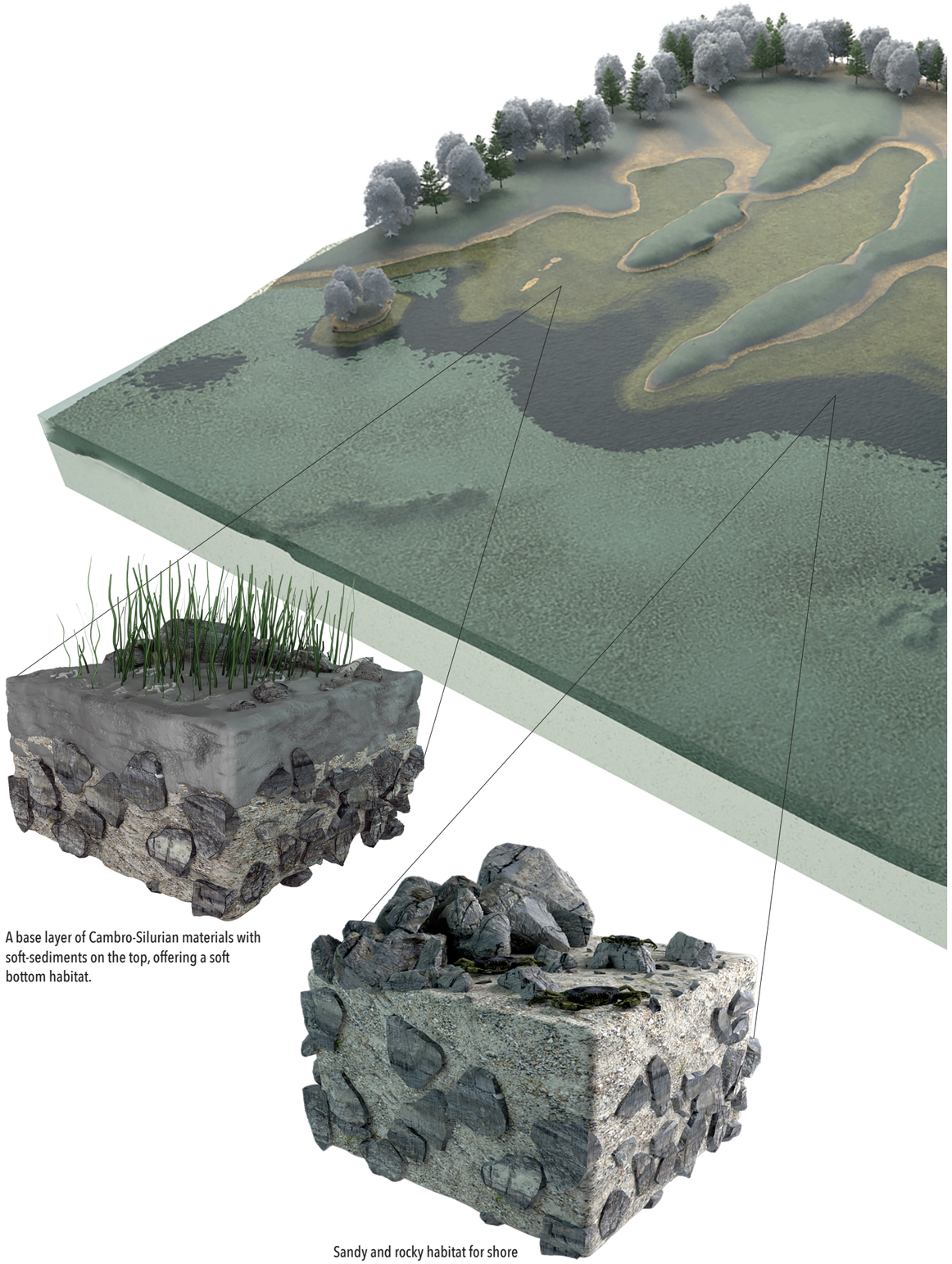
185 (Bougnères et al., professional dialogues 2020; Kourtoukov & Sørensen, professional dialogues 2019-2020)



Above: the Bispevika development to the left used as a reference for the new design to the right. In the middle: conventional load-bearing pillars to the left are replaced by new texturized structures to the right. Below: a Cambro-Silurian landscape formation placed on the concrete base of the housing quarter as a new marine landscape.

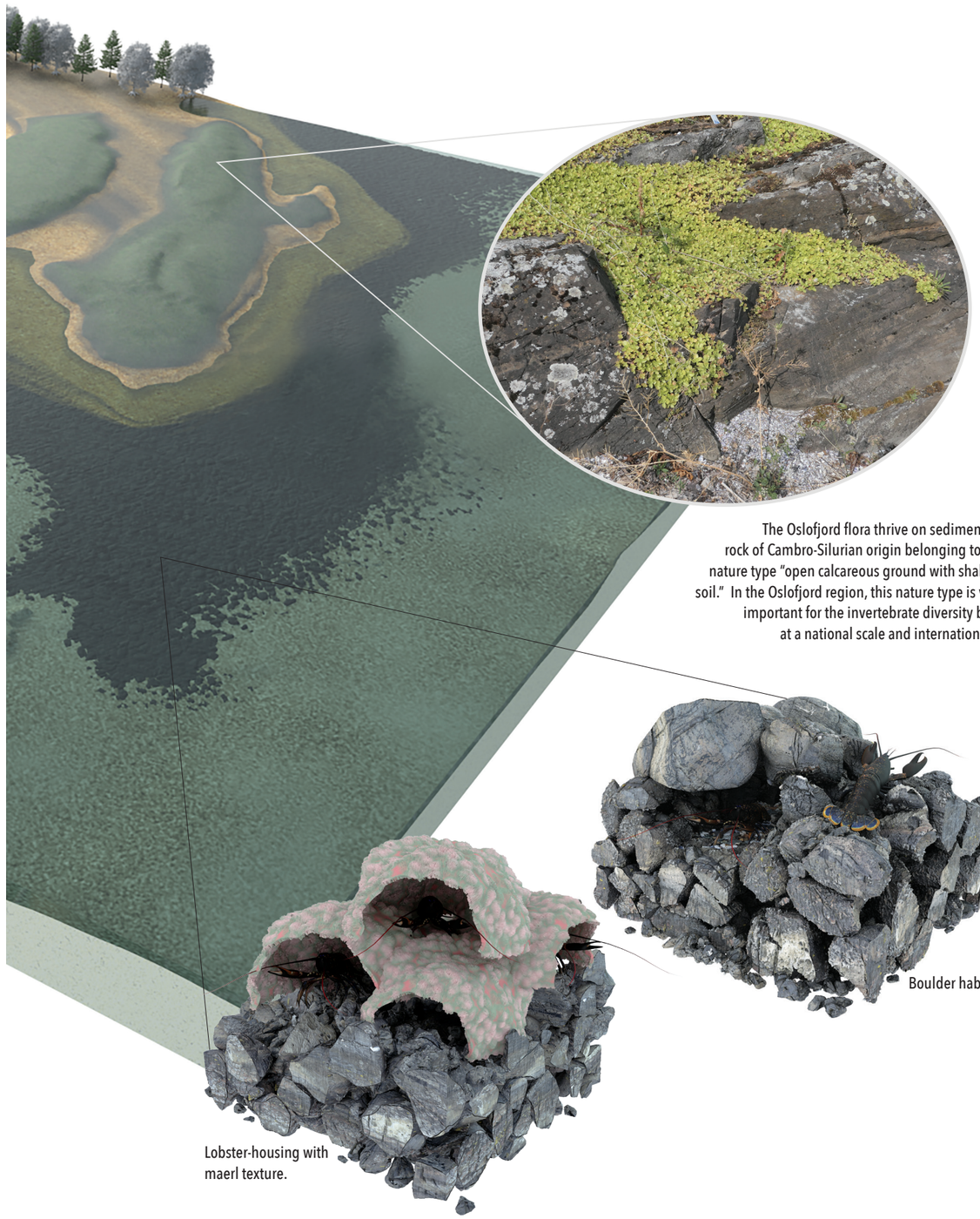


Above: example of the latest high-resolution photogrammetry model. In the middle: a rock pool structure for new marine neighbourhoods. Below: the Cambro-Silurian landscape formation offering hardbottom habitats as well as depressions for soft bottom dwellers. All 3-D visualisation by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020.



A base layer of Cambro-Silurian materials with soft-sediments on the top, offering a soft bottom habitat.

Sandy and rocky habitat for shore crabs (*Carcinus maenas*) and others.

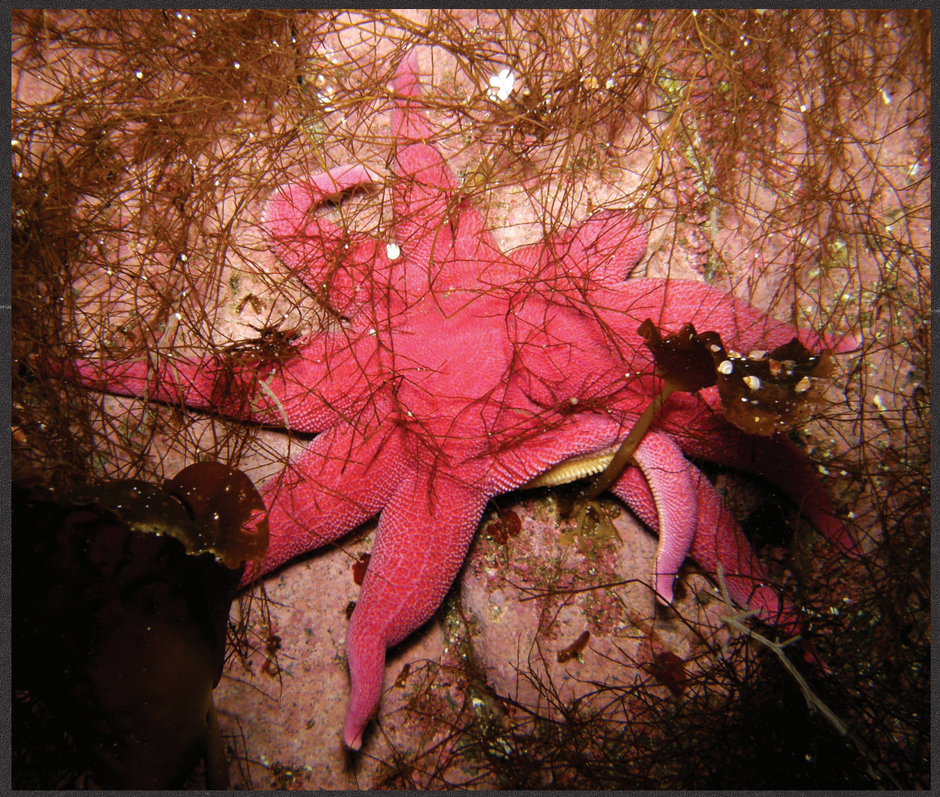


The Oslofjord flora thrive on sedimentary rock of Cambro-Silurian origin belonging to the nature type "open calcareous ground with shallow soil." In the Oslofjord region, this nature type is very important for the invertebrate diversity both at a national scale and internationally.

Boulder habitat.

Lobster-housing with maerl texture.

A marine landscape adapted for Lakseberget in Sandvika, created by local surplus rock material and designed to facilitate for blue forest and marine neighbourhoods. The four models below show examples of marine nature types and ecological functional areas such as sand and boulder habitats for shore crabs and lobsters. 3-D visualisations by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020.



A purple sunstar (*Solaster endeca*) casually resting its arm on sugar kelp (*Saccharina latissima*) growing on a coralline red algae-encrusted rock. Underwater photo reprinted with permission from Pernilla Carlsson (NIVA). The motive was found in Melfjordbotn October 2008.

Part III
Towards multispecies co-creation

Through this work it has become evident that several knowledge gaps must be bridged. By means of deep co-creative practices on a long-term basis, I have achieved change within urban development and landscape architecture which I hadn't believed was possible. In the last part of the thesis, I will recount the phases of this working process.

To go undersea and include this realm in my work as an urban design practitioner has clearly been an adventurous expedition of discovery and innovation. As described in Part I and II, the spatial examination of the intertidal revealed new insights into lifeforms and living conditions, which in turn informed the creation of a new marine landscape architecture. However, this was not enough. To connect the fields of knowledge concerned with the sea and urban development required a change in attitude. As mentioned, I had to become friends with the marine research community. Early in the process of trying to make a change, I also found myself working as an action researcher. At times this even led to taking on the role of a landscape activist by speaking up on behalf of the intertidal in various contexts, such as ongoing discussions about urban development projects. Engaging in public outreach proved especially vital to attitude-changing work. Here, each article and appearance in the media has served as an introduction to the urban coastal community of the inner Oslofjord, providing valuable feedback in return. I have come to know new places and people. For example, locals have asked me to engage in specific intertidal sites, expanding both my scope of understanding and area of fieldwork. In this way, I have gained a richer perspective on Oslo's urban sea area and the local coastal culture. By engaging in actual locations, my ideas have been tested on others throughout the process. In response to these points of contact, several communities of co-learners have emerged, with the same aim of raising public awareness and enhancing the urban blue.

From this explorative journey a realization has gradually grown upon me: a new perspective has opened, expanding my values. To erase the separation between land and sea, between nature's forces, nonhuman inhabitants and people, we must overcome the persistent attitude of human centeredness. I have started envisioning an ideal world of coexistence. Now, I clearly see that the way forward is to engage in multispecies co-creation. To change the world for the better, we must gather skills and build co-creative teams.

Exploration and serendipity

There is an adventuresome fairy-tale character whom I identify with — it is the beguiling Ash Lad. I must add that this part of Norwegian cultural heritage has fostered my imagination and learning of the world since childhood: "The hero in a folktale must first and foremost have brains — not in a bookish sense, but rather as in the ability to seize an opportunity when s/he sees one, the imagination to wriggle out of the trickiest situations, and an irreverent distrust of all figures of authority."[186] The insistence upon practice, as well as professional common sense, before theory, speaks to me. The Ash Lad is a freethinker, paving the way for new perceptions — for example, in the unprejudiced way he sees value in the most insignificant things; he collects trivial objects and becomes friends with seemingly unimportant figures. Eventually, however, all these encounters turn out to be more than favourable. In this way, the Ash Lad gains momentum, new knowledge and richness of life. Like this role model, I have explored by curiously following the flow of events. My practice strives to embody an honest, open-minded, and unrestricted inquiry. I am critical towards established systems and strive to welcome other contributions and new phenomena. Not least, co-creativity and the establishment of effective teams have been vital to my success. Hence, this thesis' line of inquiry the lead of a venturesome fairy-tale character.

Adventurous people explore; in art; in space, in the air, on land and in the sea. This is the case within science as well as in everyday life, says professor Emeritus of Sociology Robert A. Stebbins. His work comprises research methods of discovery, leisure studies and *exploratory research*. From the verb to *explore*, he draws out different directions to this practice Stebbins starts out with the most general meaning of exploratio as the study, examination, analysis or investigation of something. Next, a more specific nuance of this is to familiarise oneself with something through testing and experimentation — a mode of operation that he relates to artists, inventors, and innovators. Thirdly, exploration can imply traveling over or through a space for the purposes of discovery and adventure — which Stebbins associates with *spatial exploration*. Lastly, exploration can refer to examining something for diagnostic purposes, and since the explorer already knows what to look for, s/he only needs to methodically hunt for it.[187] In this thesis, *innovative exploration* and spatial *exploration for discovery* are most relevant.

Stebbins' term *innovative exploration* has to do with exploring by familiarising oneself with some phenomenon through testing or experimenting — for the purpose of arriving at a desired effect or product. The experimenter is mainly interested in getting to know something to the degree that is needed to refine the intervention or invention. As he writes: "The inclination to explore is satiated, once this effect or product has been created."[188] This is what separates innovative search from *exploration for discovery*. Here, the researcher is not satisfied until every important element of the area under study becomes clear. Innovative exploration is narrower and focused, whilst an exploration for discovery is broader and more thorough.[189]

Within this thesis' lines of inquiry, is hard to separate the spatial and thorough examination of the intertidal from the explorative action research that is elaborated on below. This is because the landscape of the urban intertidal and its inhabitants really are two sides of the same coin: when studying the landscape, the coastal community is part of this; and when dealing with the manifoldness of situations, people, and creatures, you soon run into accidental discoveries and must act by means of spontaneous interventions. These are instances of *serendipity*. To Stebbins, exploration and serendipity are two distinct forms of discovery. Serendipity encompasses informal experimentation, accidental finds and spontaneous inspiration. This is a state that, in principle, anyone can reach. Exploration, on the other hand, relates to practices of people who work more purposefully and methodically, such as those trained in the arts and sciences. To the untrained and amateur, discoveries and new ideas — in Stebbins' eyes — may only come by way of serendipity.

186 (Leiner & Dick, 2017, p. 6; "he" is changed to "s/he" by Elin T. Sørensen)
187 (Stebbins, 2001, pp. 2-5)
188 (Stebbins, 2001, p. 3)
189 (Stebbins, 2001, p. 3)



Habitat	Moominvalley
Species	*Fillyjonk*
Common name	Mrs. Fillyjonk

Description: "Order and strict principles are vital to Mrs Fillyjonk, wanting her rules and principles to be obeyed to the letter. Even the smallest misfortunes depress her, and she easily loses her temper. Although Mrs Fillyjonk is dutiful to the point of tedium, deep inside she is perhaps a little jealous of how freely the Moomins live. Mrs Fillyjonk is always giving her home and garden a thorough clean and tidy."
Source: https://moomin.fandom.com/wiki/Mrs_Fillyjonk

Coming across Mrs. Fillyjonk from Tove Jansson's literary universe gave sudden insight into the reality of the Fjord City as a "play." In the illustration, this character appears as an astonishingly precise personification of some less sympathetic types acting within the mentioned "scenery:" she embodies narrow-mindedness, jealousy, suspicion, and scepticism towards new ideas. The artwork in the book "What Happens Next?" shows Moomin and Mymble encountering Mrs. Fillyjonk at the shore. Finding this book, I was re-introduced to Jansson's graphic style, which further influenced the thesis' landscape visualisations. Tove Jansson (1952) reprinted by permission from Cappelen damm "What Happens Next?" 2017, pp. 12-13.

To people with a long experience in idea development, discoveries may at times be serendipitous, yet new ideas usually flow from conscious and routine exploration.[190] François Ascher, writes about the role of serendipity within urban research. Ascher embraces serendipity because it opens possibilities for discovering something that you did not search for. To him, the urban researcher cannot tackle forthcoming problems "without the ability to deploy the unexpected." Like Stebbins, he encourages the researcher to "shift from casual, unintended serendipity to conscious, intentional serendipity."[191] As Stebbins puts it, in exploring any given phenomenon, the researcher "must approach it with two special orientations: *flexibility* in looking for data and *open-mindedness* about where to find them."[192] With a nod to the manifold situations that have shaped this work, the achievements base upon an approach that truly have welcomed unexpected turns.

In extension of the deep involvement with the coastscape, described in Part I and II, an *exploration for discovery* is employed to learn from the landscape of the intertidal. This again informed the thesis' *innovative exploration*, where I was geared towards creating a product: namely a new marine-friendly landscape architecture created through experimentation with new technology and building materials. In the following, I shall recount how my explorative work developed into a kind of action research. The attempts have been to effect a real change in attitude within some of the Fjord City's urban renewal projects. In Andrew Brown's terms, I have *re/acted*: I have set out to "transform the world and change it for the better."[193]

Re/acting in the Fjord City

"All the world's a stage" says Jacques in the play "As You Like It,"[194] addressing the many roles men and women play through a life cycle. Talking about urban planning as a game or a play is a common cliché, referring to the exercise of power and behind-the-scenes negotiation. Yet, through my involvement with the Fjord City, this cliché has at times appeared as a somewhat appropriate description of real life.

Early in the research process, I found myself taking on the role of an intertidal landscape activist. Together with my mentor Anne Beate Hovind: a visionary urban developer skilled in strategic thinking, we performed lobbying activity on behalf of marine life — for instance, by entering ongoing renewal projects and participating in urban development debates. Each outreach resulted in new connections and hence expanded the work horizon, both thematically and geographically. With open enquiry as working mode, I had to hand myself over to the process and let it take on a life of its own. Following the orientations articulated by Stebbins, I sought to be a flexible data-harvester and open-minded towards the unexpected. I strongly believe that the longer you manage to keep a process open, the deeper you may reach into the matter. When searching for discoveries within an eco-social art practice, it is recommendable to drift freely with the "currents," while at the same time being very conscious about it.

Through this work, I have persistently voiced clearly and loudly our need to include life below water as an equal part of the urban landscape and coastal community. This has been a long-term experiment in creating an effect through the process of explorative action research. It became thus a journey marked by lucky (and a few unlucky) confrontations. This journey of discovery started with knocking on the door of the Norwegian Institute for Water Research. Another connection in the natural sciences led to the co-writing of the article "Utbygging i det blå" (Building in the Blue) for the magazine "Biolog."[195] This again was the start of the exchange of ideas with my geo-mentor and the idea of mirroring features from local geotopes in hardened urban waterscapes.[196] From delving into the myriad of opportunities offered by the natural rocky shore, a new trajectory began with the passion for making nature-replicas and creating new geological signatures.

190 (Stebbins, 2001, pp. 3-4)
191 (Braae et al., 2013, p. 194 [François Ascher sited by Braee et al.])
192 (Stebbins, 2001, p. 5)
193 (Aure, 2020, p. 139; Brown, 2014, p. 218)
194 (Shakespeare, 1993/1599)
195 (Sørensen, 2018; Sørensen et al., 2018)
196 (Nystuen & Sørensen, professional dialogues 2017-2020)

To test how the planning community would receive these design concepts for improving the living conditions for marine life and people, I had to knock on the doors of property developers, contractors and city administrators. The belief in living blue-labs as potential agents of change, covered in Part II, led to numerous meetings with caseworkers at Oslo's Planning and Development Service: this process went on for almost a year yet led nowhere. The launching of initiatives and carrying them through obviously requires a clear mandate from some authority. As an exception, however, some outcomes of the thesis are due to my contacting Anne Beate Hovind — who has been involved with Oslo's waterfront for the past 20 years. In hearing about the focus on ocean literacy, her immediate response was "this is a cause I want to help promote."[197] Her talent lies in the ability to lead a broad set of stakeholders towards a shared vision of realizing unconventional development projects. As she puts it: "Art can influence one individual, or even an entire generation, and work as a catalyst for change. Art has the ability to connect you to your senses, body and mind, and make the world *felt*."[198] From the day she took the project under her wings, things started happening. Not surprisingly, along this study's research trajectories many things went far beyond expectations. The extensiveness of its explorative expeditions is reflected in the number of people, situations, organisms, experiences, artefacts and tools, each of which have provided their own unique perspective. Not all of these can be mentioned. However, I will describe a few *re/actions* with the Fjord City.

What about new urban undersea quarters along Oslo's waterfront?

From 2017 to the present, we have pursued the initiation of living blue-labs. The closest we have come to actual implementation is the proposal for the Bispevika quarter described below. As a prelude to this, Hovind and I — as a volunteer intertidal activist team — had the opportunity to participate in several meetings in 2019 concerning waterfront renewal. Here we encountered a wide array of stakeholders, including real estate company owners, project developers, masterplan caseworkers, architects and representatives from the City of Oslo. These meetings gave us the chance to speak up for coastal eco-engineering methods. We launched the term *intertidal signal landscape*, arguing that the landscape undersea must be treated with the same respect and consideration as in the realisation of the magnificent and nationally supported Oslo Opera House. Furthermore, we introduced the idea of *blue stewardship* by proposing that the City of Oslo engage a team of underwater gardeners to care for life below water. Others picked up the idea after we published an opinion piece in the newspaper Dagsavisen in July 2019. The article led to, among other things, a request to participate in the festival "Youth for a Clean Oslofjord — Underwater Gardeners NOW!" The event was organised by *Save Oslo's Seas* (SOS), a group of high school entrepreneurs that had launched a petition for the cause.

Our encounters with the development community had their high and low points. Sometimes we left feeling uplifted, and at other times the scepticism and resistance we met made us question whether we would ever succeed in our mission. Nevertheless, we had been noticed. During the summer 2018, we were invited to talk at several urban development seminars. At one of these, we unintentionally came to provoke a key real estate company stakeholder. Subsequently, our official collaboration was terminated on one of the fjord site renewal projects. Despite this, the two of us continued to engage exploratively as an "intertidal activist team." One collaborative act was the founding of the association Friends of Kongshavn, inaugurated on May 19, 2018 and followed up with the Facebook community blog "Kongshavn Bad:" https://www.facebook.com/Kongshavn-Bad-209657369813892 . To offer a bit of context, Kongshavn is the urban demolition waste rock fill described in Part II, partly built by material from Sjursøya island. The place can be characterized as a wasteland. Still, the view from the landfill headland towards the city centre is stunning, and hence, it is a coastal site deserving of attention. "The Kongshavn Bad" blog was quite active during 2018 and eventually attracted 320 followers. This led to, among other things, an engagement to carry out a feasibility study for a temporary industrial parkland at Kongshavn on behalf of the construction group Skanska — briefly described in Appendix II. From April 2018 and onward, Eli Rinde at NIVA joined on a regular, yet voluntary, basis. In the following, the constellation of the three of us is called the "urban intertidal team."

197 (Hovind & Sørensen, professional dialogues 2017–ongoing)
198 (Hovind, 2019)



The sketch that caused trouble: in the drawing an organic shoreline formation that mimics the natural rocky shore shoreline replaces the industrial port landscape. I was curious to see what it possibly could look like if the excavated seafloor was lifted for the sake of improving the conditions for both marine life and people. To deploy rock fill material into the sea, however, is more technically challenging than on land, and thus, a costly procedure. Among other things, the risk of churning up polluted sediment is a serious environmental issue. Still, regarding the human footprint along urbanised waterfronts, I believe that previous building activity must be thoroughly re-thought and current building practice must be re-considered. Drawing by Elin T. Sørensen © BONO 2018.

Eelgrass, blue mussels and marine enthusiasts in Malmö

In August 2018, Hovind and I went on a field trip to Malmö in the southernmost county of Scania to learn from their approach to the urban blue wildlife. We met Michael Palmgren, founder of The Marine Education Center Malmö, and Åke Hesselkrans, architect and caseworker at The City of Malmö. They have carried out an eelgrass restoration project that was initiated from a need to deposit surplus rock material from another construction site. To build eelgrass meadows, they filled 130.000 m^3 of the surplus limestone aggregate on the excavated seabed of the former industrial port Kockumsrännan. Since initial planting in 2012, viable eelgrass communities have eventually emerged and spread in this new urban shallow water environment. Based on this experience, several eelgrass meadows have been established in the city centre's waterscape. Believing in nature's self-design, Palmgren explains that the restoration has been successful because much of the restoration work was left to the eelgrass itself. One reason why the marine plant thrives so well is that blue mussels filter the surrounding water, hence, the interaction between blue mussels and eelgrass is an essential precondition for success. Another factor is that one of the world's largest continuous eelgrass beds is found nearby, with plants growing in depths of 9-10 meters. What is more, in areas around the bridge connecting Malmö and Copenhagen the blue mussel colonies extend up to 73 square kilometres, contributing to a natural colonization of the bridge's 54 pillars. The municipality has now banned bottom trawling to avoid sediment disturbance, which would create poor light conditions for marine life in the area. Regarding port transformation, Hesselkrans pointed out that the lifting of the seafloor is also motivated by safety concerns in connection with drowning. A varied coastline including shallow water, he explained, is far safer for people than the international port standard of 6-9 metre water depths intended to accommodate large and heavily loaded ships.[199]

So close to seeing an undersea-lab come alive in Bispevika

Starting in the spring of 2018, the urban intertidal team voluntarily engaged in a demo-case for Bispevika. The task was to make space for marine life within the submerged part of a new housing quarter — which at the time was already in the construction phase. We became interested in doing something here after Hovind heard that the project developer was considering establishing eelgrass beds on the concrete building foundation. What happened next is recounted in the timeline below. This chronological account exemplifies the process of *innovative exploration*. The knowledge gained in this experiment is referenced in paper #3, Appendix I. The following focuses on some other aspects of the process.

In my initial encounter with the project developer on June 6, 2018, he responded enthusiastically to the presentation on coastal eco-engineering and how valuable eelgrass is as a habitat-forming species. We left the meeting highly inspired. At the beginning of August 2018, the urban intertidal team and project developer started discussing how we could make the soft habitat species eelgrass thrive in this submerged hardscape. We came up with the idea of creating miniature undersea landscapes from rock material that could house both eelgrass and hard bottom communities. The project developer explained that the building structure stands on a concrete foundation deck supported by a great number of steel piles anchored to the bedrock. To keep the building pit dry, seawater was held back by means of a Larssen steel sheet piling retaining wall. This would make it possible to retrofit marine landscaping solutions within the submerged parts of the construction before the seawater was released back, which we were told would happen during summer 2019.

Between August 2018 and March 2019, Eli Rinde and I made plans and models for the intended marine biodiversity enhancements. On October 16, 2018, we examine the site on a fieldtrip by boat — joined by several marine biologists from NIVA, the project developer and a political advisor and science writer from the NGO Sabima. The preliminary concepts for Bispevika were included in a poster for the International Temperate Reef Symposium in Hong Kong January 2019.[200] Late autumn 2018, this material was presented to Ard Innovation (NMBU/NIBIO), which decided to prioritize the project and assist in the commercial- development of the marine landscape architecture. Their support made it possible to engage in the digital fabrication and 3-D visualisation described in Part II.

199 (Palmgren et al., professional dialogue August 8, 2018)
200 (Hovind & Sørensen, professional dialogues 2017–ongoing; Rinde & Sørensen, professional dialogues 2016–ongoing; Sørensen et al., 2019)



Left: intertidal fieldwork October 16, 2018: a marine biologist looking for marine life at Ormsund in the inner Oslofjord.
Right: the team of marine biologists, the project developer, and the landscape architect in the Bispevika building pit.
Photos by Elin T. Sørensen © BONO 2018.

For the miniature undersea landscapes, I began by looking into how to access local excavated Cambro-Silurian* surplus rock material. Following a lead from my geo-mentor, the search starts with the ongoing infrastructure projects in Bærum municipality. This led to discussions with several caseworkers working with the municipality's mass management strategy. Bærum already had some experience with creating new landscapes, such as Kadettangen Fjord Park, where they re-used 600.000 m^3 local rock. This project shows exemplary environmental mass management in regard to the handling debris and plastic from the tunnel excavation. However, marine restoration was not a focus in realizing the fjord-park. A breakthrough in the search for Cambro-Silurian surplus rock finally occurred at the end of October 2018, when I got in touch with an engineering geologist at the Norwegian Public Roads Administration (NPRA) who was willing to offer a visit to a tunnel in Sandvika and possibly provide rock. Now I had to access appropriate materials for the underwater landscapes in Bispevika. The geologist explained that Cambro-Silurian rock is unattractive to the building industry since it provides little wear resistance as a mineral filler in asphalt and is neither suitable as base for road construction nor for building pits.[201] For the restoration of the urban intertidal and marine life in the Oslofjord, however, this specific Cambro-Silurian material is very well suited.[202] The thesis practical works, as presented in the video "Marine Landscape Architecture" and the Cambro-Silurian imprints cast in Jesmonite are some examples highlighting this.

The rock inquiry resulted in some insights of interest on a general level to the thesis topic. Because the enormous amount of rock material produced large-scale infrastructure projects has environmental ramifications, attention must be given to how excavated materials can be sustainably re-used. As just mentioned, such excess local material may be suitable for facilitating local marine species. In the creation of new marine landscapes, variation in the size, texture, and shape of the rock material must be considered. It goes without saying that risk of negative chemical effects from radon, sulphur, heavy metals or plastic content is highly undesirable. Concerning logistics, the ideal situation is to temporarily store masses for sorting the rock material. Weathering processes are beneficial before arranging the material undersea, hence it can be useful to keep the material uncovered on land for several months. During the construction and operating period in the sea, monitoring programs must be deployed to safeguard marine life from debris and other potential pollution. Comprehensive planning and continuous dialogue at all levels is crucial to the creation of artificial land formations, including logistical issues and cross-disciplinary workflow. Long-term perspectives and coordination between stakeholders are key success factors. Since there is little experience with the creation of marine landscapes from the re-use of local rock material, such projects should be treated as learning platforms for the many parties involved.

201 (Stenerud & Sørensen, professional dialogues 2018)
202 (Nystuen & Sørensen, professional dialogues 2017-2020)

This includes public education activities, such as Citizen science practices, by which public involvement in research can contribute to scientific knowledge.[203] The Living Breakwater and the Billion Oyster Project, located off the South Shore of Staten Island NYC, involves both creating oyster reef habitats, and educating local community members about the importance of this work and how they can participate. This is one example of combining large-scale infrastructure and habitat enhancement with community engagement.[204] Living Breakwaters is shortly presented in Appendix II. The local use of rock materials from major infrastructure projects is a topic in the NIVA reports, which are summarized in Appendix II.

From this detour to Bærum municipality, I return to Bispevika. In the beginning of March 2019, the urban intertidal team, headed by Hovind, was invited to meet the contractor, project developer and a representative for the contracted landscape architects working on land. Due to a shortage of time before the expected release of seawater into the building pit in the summer 2019, we agreed to aim for retrofitted eco-engineering solutions, such as modular diversity enhancing settlement surface for the loadbearing pillars, submerged walls, and the concrete base. With respect to the Management, Operations and Maintenance key (MOM) and the contractor's 5-year warranty for construction works, it was decided that all solutions must be designed for easy removal if anything should fail. Regarding the undersea landscape, we found the responsibility for maintenance to be unclear: where does the landowner's responsibility stop, and the municipality's Agency for Urban Environment take over? In the name of ocean literacy, we agreed that all eco-engineering measures must be monitored. Also, the anticipated new interventions must build on experiences from earlier small-scale undersea pilot projects by the Oslo Opera House (2010), Tjuvholmen (2011), and Sørenga (2013). We rounded off by envisioning a higher level of ambition for undersea landscaping for the next building-phases of the Bispevika housing quarters. However, at the very end of the meeting, the contractor informed us that placing a marine Cambro-Silurian rock landscape on the concrete foundation and the proposed drill-hole pattern design for the loadbearing pillars are impossible to implement.

As a follow-up to the above, Rinde and I were invited to set up a plan together with the contracted landscape architects. Our common aim was to plan for appropriate water quality improvement and marine biodiversity measures for the building site. The head landscape architect took responsibility for integrating the marine considerations into the project management. Rinde and I the task of making a cost estimate for designing marine neighbourhoods for all new housing quarters in Bispevika. Quite unexpectedly, however, it was suddenly decided to remove the retaining wall and release seawater into the building site on April 2, 2019. The change of timing made the proposed marine landscaping impossible to carry out. A year later, in April 2020, I was requested to provide input to the masterplan for the next development stages. This meant I had the opportunity to contribute with a marine landscaping statement for the preliminary conference at Oslo's Planning and Building Services. Hence, there is hope of eventually arriving at a clearer and more unified framework for the planning and design of a marine-friendly urban waterscape. Only time will tell.



Tunnelling work in Sandvika January 11, 2019: Cambro-Silurian material is especially favourable to local marine species, as the tidalscapes along the inner Oslofjord mainly consist of geological formations dominated by slate and limestone from the Cambro-Silurian period,[205] the common term for the three geological periods Cambrian, Ordovician and Silur dating 419-541 million years ago. These geotopes are typical for the Vollen Formation that can be studied in many places in Oslo, especially west of the Akerselva and at Filipstad together the rognerkilen Formation.[206] Photo by Elin T. Sørensen © BONO 2019.

203 (Ullrich, 2012)
204 (The American Planning Association APA, 2017)
205 (Nystuen & Sørensen, professional dialogues 2017-2020)
206 (Universitetet i Oslo, 2020a; Universitetet i Oslo, 2020b)

A community of learners

The interaction with all those involved in the planning and building process, as described above, plays a decisive role in *innovative exploration*. I dare say that the general concern for life below water in the Fjord City development was absent until the urban intertidal team drew attention to it. Our efforts have for the most been voluntary and parallel to rather than an integrated part of official project management. This has been a major limiting factor in our efforts to affect change. At the end of 2018, after several stranded site-specific experiments, I suddenly recognised that the urban living-labs were growing right before my eyes: not as physical test-sites, but as an emerging community of learners that included the people we had approached with their different interests in the urban waterfront.

Undisciplined collaboration

As you probably have realised by now, this is study based upon a dialogic approach. "Dialogue" comes from the Greek; combination of *dia-*, which means "across" or "between," and *legein*, which means to "speak" and to "collect" or "gather," as in "to 'pick out words."[207] The word "dialogue" might thus be interpreted as moving across speech in order to harvest knowledge.

From working as a landscape architect consultant in the private and public sector, I have most often experienced each field of expertise as producing advice independently, that is, without acting together. I believe this to be counterproductive to conquering the piecemeal and fragmented tendencies of urban planning and development, not to mention a more inclusive multispecies perspective. In this respect, this form of research resides in-between knowledge cultures and moves across practices, attitudes, and even various species' interests. Therefore, our eventual encounter with the term *undisciplined*[208] was a relief: in seeking to ground the doctoral work on deep collaboration and co-creativity, it became a necessity to undiscipline. The following paragraphs elaborate on the role of undisciplined collaboration.

Moving in-between

In-betweenness is relational, manifest in the language we use, both visual and verbal, and in the way we do things. As a landscape architect going undersea and being dependent on other fields of knowledge, there have been many boundaries to cross. Sometimes I've gone astray, bewildered by the different and yet relatively similar terms that might describe the kind of interaction implied by prefixes like inter-, cross-, trans-, multi-, pluri-, and post-disciplinary. This confusion is expressed within architectural research too.[209] Seemingly, there is general agreement that these conceptual siblings involve a form of cooperation that goes beyond merely putting things together. Rather, the debate is more about distinguishing differences. The architectural researchers Isabelle Doucet and Nel Janssens attempt to sort out the "plethora of terms deployed to describe the different modes, methods, and degrees of combining disciplinary knowledge."[210] Interpreting transdisciplinary as a "hybridisation of knowledge and modes of inquiry," the authors suggest this term to be especially relevant to architecture and urban planning. This is because the term suggests the synthesis of different disciplines and professions that together combine theory and practice and most often deploy experimental, designerly ways of examination.[211] Discussions on the interaction between different professions seem to be linked to a need for articulating and defining each field's autonomy. The landscape architectural researchers Ellen M. Deming and Simon Swaffield write about how to frame the distinct point of view of their profession. Of course, they say, professional boundaries are always historically responsive regarding social and environmental contexts, and hence we must never stop debating. The basic position of landscape architecture, they argue, relates to "stewardship — the protection and enhancement of the conceptual, material, and phenomenal relationships between human culture and nonhuman nature. This mandate is partly what distinguishes landscape architecture from, say, architecture, but also relates it to other, synthetic or hybrid disciplines such as urban forestry.

207 (Etymonline, 2020b)
208 (Hessler, 2018b, p. 32)
209 (Doucet & Janssens, 2011)
210 (Doucet & Janssens, 2011, p. 1)
211 (Doucet & Janssens, 2011, p. 2)

The most important function of an autonomous iscipline is the construction and maintenance of a specialized body of knowledge."[212] Within this discourse, some argue that it is only when a discipline has acquired its own identity that it is able to contribute to fertile, transdisciplinary activity.[213] However, I'm left with the question whether our specialisation may also come in the way of good results.

An un-learning–learning cycle

The anthology "Tidalectics – imagining an oceanic worldview through art and science," offers new perspectives on dialogic imaginings across mental, cultural and physical borders.[214] Here art curator and writer Stefanie Hessler and art collector Francesca von Habsburg propose art as an arena where people can form new connections. This is analogous to coastal landscapes as places of exchange between ecosystems, mentalities and fields of knowledge: places from which new relations and hence knowledge grow. Against this fluid backdrop, artistic practices are thought to produce a much-needed porosity, offering manifold views that inform one another and co-exist. The authors point to the traditional divisions between professions, perceiving them as obstacles to the exchange of information, and hence, the development of common understanding. Art is seen as a potential "glue" between disciplines. The artistic drive towards entering the unknown and testing boundaries inspires an "undisciplined" mindset. Hence, to undiscipline is suggested as a prerequisite for real interaction to take place.[215] In the context of teaching and learning, Professor Emeritus of Visual Arts Education Ulla Lind speaks of her efforts to un-learn "understanding" and the search for "the meaning." The reason for this is that the hunger for "understanding" and "explanation" often stands in the way of accessing insights more deeply.[216] As a kind of disobedience against ready-made templates or normative patterns, this is clearly linked to operating undisciplined — not for the sake of being against something, but rather for the sake of searching for insights in new ways. At this point, I must again refer to Rachel Carson. In her last book she encourages us to learn about nature through all our senses and to abandon the impulse to teach, explain, systematise and understand.[217]

When interacting with different disciplines or fields of knowledge, you step into the mental realms of others. This requires having to step out of your own role as an expert and become a beginner. Having no prior knowledge of marine biology, this is what I had to do in this doctoral study. Coping with the contradictory state of expert/beginner requires patience and trust, and, ultimately, the acceptance of results that none of the participants may have predicted. Taking on a state of expert/beginner requires that the parties have an ability to give up preconceived ideas along the way. The professional confidence that eventually developed within the urban intertidal team through a long-term, undisciplined and deep collaborative practice, is a major accomplishment of the thesis' explorative action research. Regarding the multispecies co-creation that is elaborated on below, the ability to challenge and eventually erode assumptions and prejudice towards the realm of nonhumans or other unfamiliar situations is paramount.

Co-creativity

The last paragraphs of this thesis pave the way for what can be termed *multispecies co-creation* — an idea that came about in the making of the exhibition "HAV." The artworks' co-creators were introduced in the exhibition entry hall and can be found at RC: https://www.researchcatalogue.net/view/869494/980409 . Hence the extensiveness of the thesis's explorative expeditions is reflected in the number of organisms, experiences, people, situations, artefacts and tools involved: each of which have provided a unique input and perspective. As a prolongation of this, the concept of multispecies co-creation is tested as a participatory method that aims to improve the cohabitation between species on land and at sea. This implies trying our best to treat the animals, plants and humans that live in a place on an equal basis. For instance, when we include the marine creatures and those living on land, a myriad of species emerges in the neighborhood. This is a diversity worth knowing.

212 (Deming & Swaffield, 2011, p. 18)
213 (Pinson, 2004, p. 503)
214 (Hessler, 2018a)
215 (Hessler, 2018b, p. 32; von Habsburg, 2018, p. 8)
216 (Lind, 2015)
217 (Carson, 1998/1965)

Therefore, by this method, the stakeholders of a site development are encouraged to ally with the nonhuman others that are affected by human behaviour and intervention. As a hopeful action, this may be a way to give their behavioural expressions greater significance in our lives.

This practice will be explored in the community art project "Under/sjø" (Under/sea) located at Ormsund, south-east of the Oslo city centre. The project is developed by a core group including Hovind and me, the community association "Fjordtunet," the local free diving club "Spearos Oslofjord," researchers from NIVA and a representative from Sabima: an umbrella organization for biological associations in Norway. Our overarching aim is contributing to children and young people's knowledge and empathy for marine nature, to awaken hope and lasting commitment, and encourage their belief in that they have the power to make the world a better place. In a first attempt to get to know the marine community, the free divers are engaged in an underwater census, organized as crowd sourcing. To make the results useful to the marine research community, the collection of data is based on mapping guidelines from NIVA. Nedre Bekkelaget School is another local participant: including a group of thirty 7th grade pupils and their home room teacher. The idea is that the children will perform research on life below water as part of their schooling and help us write a brief story characterising some of the native species. These pupils will become the "mini-school-teachers" for next year's class of students during a two-week summer teaching program in June 2021. One intended result of this anticipated multispecies co-creation is a public art piece in the form of a locally adapted marine life-friendly snorkelling trail.

The multispecies city

The above approach is inspired by the idea of multispecies cities. This concept, as explained by field philosopher and storyteller Thom van Dooren and his writing partner, ecological ethnographer Deborah Bird Rose (1946-2018), transformed my perception of Oslo's urban foreshore. Multispecies urbanism addresses the role and life conditions of nonhuman others within the urban context. Rose and van Dooren draw attention to how others than ourselves become attached to places, and how these place- relations carry specific stories. Their reflections are inspired by the Estonian biologist Jakob von Uexküll (1864-1944). Uexküll is known for establishing biosemiotics, a field of research concerned with prelinguistic "meaning-making," that is, the production and interpretation of signs and codes in the biological realm.[218] As told in the section "The seashore and its inhabitants" in Part II of this, marine animals interact with their environment in manifold ways. Because organisms perceive and respond to their environment from sensory impressions, Uexküll argued that they must be considered as living subjects.[219] He proposed to "investigate how environments are meaningful to animals — how the 'life story' of an animal develops according to its own perceptions and actions."[220] By studying how the senses of various creatures — like sea urchins, jellyfish and sea worms — work, Uexküll built theories on how they have a subjective experience of the world.[221] A related term is *site fidelity*, a phenomenon common to birds, fish and other creatures. The biological term for this is *philopatric*, literally meaning "loving one's home." In biology this relates to how, for instance, some birds always return to their birthplace to lay eggs.[222] The above ideas helped me to realise the substantial knowledge gap on our behalf regarding the creatures we share space with. With respect to participatory methods, I became aware of other user groups and their situation like the birds that frequent the urbanised beach at Frognerstranda and its small remnant of a wetland. The sea birds often outnumber the people visiting the beach. However, the space left for them is severely altered and has seemingly few qualities providing for the birds' well-being.

Reading about multispecies urbanism and biosemiotics changed my attitude opening the way for new landscaping approaches. We generally learn and know so little of nonhuman others. So, what is required to let as many different forms of life as possible flourish in the city?

218 (Barbieri, 2008)
219 (von Uexküll, 1934/1957)
220 (van Dooren & Rose, 2012, p. 3)
221 (van Dooren & Rose, 2012, p. 3)
222 (van Dooren & Rose, 2012, p. 8)

Looking at coexistence from a practical angle, the question I seek to find an answer to is what does it really mean to share space with other living beings — and how can we possibly treat them as active participants in shared social worlds? In the below, I will explain my attempt to include and learn from marine life.

Multispecies landscaping

To succeed as a marine architect, you must learn from the very best builders in the marine environment — namely, the marine species themselves and, of course, the sea. The making of houses for shore crabs requires one to be with them and learn from them. That is the basic idea behind engaging in multispecies co-creation. If you can't find the crabs, the lobsters, or the sugar kelp, you must look for someone that can speak their case, like a marine biologist. Moreover, you must read and look at any material that can give you new insights into your potential new friends. Like an experienced landscape architect with highly developed skills in planting, you must make your relation to the living material concrete and physical; for instance, by taking out a ruler and drawing a 40 cm line that is the length of an adult common lobster, or a 6-8 cm line which is the size of a shore crab. Another trick is creating a reference set by collecting periwinkles of all sizes or the exoskeletons shed from moulting shore crabs. By keeping these finds with you and studying them daily, you may eventually "connect" and have the facility to imagine the creatures' size and need for shelter. The next step is to study their preferred menu, needs throughout their life cycle, and who they interact with. As the marine biologists say, "knowledge on habitat use, animals' mobility patterns and dietary choices are essential to maintain bio-diversity."[223]

After a while, you learn know the crab, lobster, periwinkle and sugar kelp a bit more intimately. What emerges is a kind of indirect friendship that is far better than ignorance. From these simple rules of thumb, we can figure out how to make suitable dwellings in marine-friendly materials. Furthermore, we need to plan for how the houses can be placed in the sea, which authority we must seek permission from, follow who moves in and determine how the new intertidal community can be maintained. This is at least how I have pursued co-creation with the creatures of the sea in the attempt to act as a marine friendly landscape architect. The experiences gained from this co-creative effort have influenced how I look upon and think about the urban intertidal. This has become my foundation for articulating a marine landscape architecture.

Building blocks for a marine landscape architecture

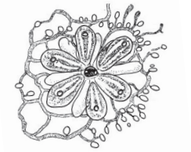
As we have learnt, some human-built environments — such as urban seafloor deserts — need help in order to restore marine life. This has motivated designs that mimic a broad set of local intertidal habitat types. As a general principle, variety improves diversity. However, is it important to keep in mind that the habitat's ability to support its associated species is what defines a well-functioning ecosystem. A species-poor or stressful environment is not necessarily synonymous with a poor place. For example, an estuary with high sediment rate may serve as a specialised habitat with a naturally low species diversity.[224] Nevertheless, in respect to this thesis' aim of making space for the kind of diversity that could appear within the urban intertidal — if we only notice it and treat it right — the following list of ideas provides some in-puts.

From fragmentation to connectivity. Reclamation of urban shallow coastal areas by repairing uniform landfills and enhancing the artificial environments of urbanised shores can contribute to marine landscape ecological connectivity. One possible solution is to facilitate a marine "pollinator strategy" by offering vital undersea stepping-stones for intertidal communities. This can be compared to landscape-ecological measures on land, like *The Pollinator passage*, or *The Bee Highway*. From the launce in 2015 until today *The Pollinator passage* has expanded throughout the city of Oslo, creating vital stepping-stones where pollinators find food and shelter.[225] Such blue-green connectivity has the advantage of making the urban bluescape resilient and experiential.[226]

223 (Christie et al., 2005, p. 14)
224 (Nystuen & Sørensen, professional dialogues 2017-2020)
225 (ByBi, 2019)
226 (Eli Rinde et al., 2019b)

From artificial hardscapes to amphibious tidalscapes. Harbour infrastructure, pontoons and floating docks in urban sea areas influence the body of water and its inhabitants. New interventions should be based on a profound understanding of hydrology and marine nature types. The human-built environment should be created as a multifunctional system that can withstand change and coexist with living systems and the forces of nature. Lessening ground impact by using lightweight structures or buoyant foundations are examples of architectural interventions that yields to nature dynamics.[227] Such approaches would facilitate waterscapes' self-design: allowing for natural changes and more unrestricted water movement, and the deposits and landforms created by the water, under and in-between the constructions. In the context of re-naturing of Oslo's artificial shore, the remaining estuaries of the urban rivers would benefit from nature-inspired and amphibious designs.

From uniform housing quarters to multispecies neighbourhoods. Instead of just building to meet human needs at a kilometre and meter scale, we can create heterogenous spaces with variation in colours, forms and structures on the meter-centimetre-millimetre scale. As I conclude in the mussel essay, in Appendix I: "We have the option to adjust and rethink our built environment, both on land and undersea. Our artificial structures can be made complementary in ways that only imagination sets the limits."[228] A variety of hard bottom and soft bottom communities based on local marine nature types and geotopes can inspire such designs. Concerning material choices, we can learn from local rock mineralogy and composition, or else use healthy, marine friendly materials and strive to avoid plastic and contaminating composite materials in the sea. It is also important to create constructions that allow for water exchange and provide light for the creatures undersea. In this way we can achieve neighbourhoods for species that promote each other's presence, in sum effecting diversity and inclusion on a broad level.



To deeply account for the inclusion of nonhuman others means dealing with a great many questions. Undoubtedly, we need the sea and we benefit from the well-being of its creatures. Yet, seeing the world from their perspective is hard: can we ever conceive how barnacles, or blue mussels could take any pleasure in becoming part of our world? I can only speak from the position of being trained as an artist and landscape architect: and obviously I fall short unless teaming up. This leaves me with the key-question of how we may reach out to organisms that we cannot talk to — and that most likely do not need our presence.

To lead our world towards a better state and in a more resilient direction, the notion of multispecies co-creation needs to be taken seriously. This can only be achieved by thoroughly acknowledging nonhuman others' needs and life strategies. With wonder and engaged interest we may learn to share our environment despite our differences. If we invite them into our ways of developing neighbourhoods, residential areas and cities, multispecies co-creation may influence the formation of a new landscape architecture reaching into the sea, and none the least new ways of performing urban coastal development. This study offers some initial clues and conceptual tools to such practices.

227 (English, 2009)
228 (Sørensen, 2020, p. 60)

Reflective summary

Having taken the step from a land-based existence and challenged my earth-bound senses by venturing into the sea, I have manoeuvred through manifold perspectives, attitudes and realms. This journey has been altogether transformative, not only to me but to the many people encountered along the way. Between some of us, deep co-creational ties have been established which will be refined in the continuation of our work. We now form a community of learners. Our mission is to inspire others to become ocean-wise by increasing insight, wonder and appreciation of our lifegiving bluescapes.

Acting through a landscape architectural practice and by artistic modes of operation — awareness of this landscape has been raised. The urban intertidal has become visible and a new world has been opened to me and others.

Moving between land and sea within the urban context entails crossing disciplinary boundaries and work cultures. In this landscape, one must navigate between different interests and perceptions about what matters and what is the right thing to do. After having been introduced to the leading research within the branch of coastal eco-engineering, I set out to find answers to what would motivate people to invest in an invisible world. How can coastal communities be improved through urban development processes that take life below water into account? By working together for several years, a core team consisting of myself, a recognized marine biologist, and visionary urban developer have initiated processes of change by *re/acting*[229] with the ongoing developments of the Fjord City by the inner Oslofjord.

One key lesson of the collaboration is that co-creation must be founded on mutual interests. All parties must see the benefit of crossing their professional boundaries and be able to empathize with others' opinions, work cultures and perspectives. For real co-creativity to occur, you must arrive at a situation where all parties need something from each other. The next question is, what does it take to get there? Refining one's own professional skills as well as showing a keen interest and humbleness towards the others' fields is vital. As the main point is to make something new together, patience and the willingness to give up "good" ideas are advantageous. By sharing experiences while thinking and doing together, the co-creators develop ties that may eventually lead to a professional friendship. The nuance added by "friendship" allows for responsiveness and interdependencies and hence professional trust. For example, this thesis' practical work reached a breakthrough when the marine biologist I had established a close dialogue with over years, was herself asked to take part in material explorations at the Norwegian Technical Porcelain (NTP) factory. The artistic drive towards entering the unknown and testing boundaries inspires an "undisciplined" mindset.[230] Followingly, to "undiscipline" is put forth as beneficial for real interaction to take place. What is gained is a new outlook on one's own practice — regarding both its strengths and weaknesses.

Rachel Carson's writings have enlightened and directed this work. She encourages us to learn through all our senses and to abandon the impulse to teach, explain, systematise and understand.[231] Her *ethic of wonder*[232] helped me articulate the part of the thesis' knowledge-building process that departed from multisensory learning. Seasonal one-to-one tutorials with a most excellent teacher, namely the tidalscape itself, have made for the most rewarding learning environment. Letting one's daily life experiences be physically and emotionally enhanced by wonder is a very simple method to follow. As a work practice, an ethic of wonder encourages a receptiveness towards the vast ecological community we take part in and that inherently deserves preservation and protection from being depleted. Consciously feeling and listening to the dynamic environment expanded my horizon, and hence, my insight into the marine environment has broadened substantially. Even though I failed to complete the CMAS One Star Diver Training Programme, snorkelling has become indispensable to an investigative practice connecting me to the tidalscape and marine life. The dynamics of waterscapes, from their intangible qualities to their dramatic changes over time, had to be represented: for instance, grasping and communicating a fluvial process or the scale of predicted flooding. The animated pilot "Landscapes with a Soul" is one effort to articulate and convey this.

229 (Brown, 2014, p. 218)
230 (Hessler, 2018, p. 32; von Habsburg, 2018, p. 8)
231 (Carson, 1965/1998)
232 (Carson, 1965/1998)

Environmental ambiences closely relate to humans' and nonhumans' well-being. Therefore, multisensoriality as an analytical tool and means of expression is essential to urban planning and landscape design that incorporate nature-based solutions.

The world's coastlines are increasingly densified and cluttered with infrastructure to meet the needs of humans. These hardened, urbanised coastscapes call for diversity, inclusiveness and shoreline softening. To prepare the urban sea areas and their coastal inhabitants for the future, we should trust and recognize nature's capacity for self-design — and let nature-based solutions develop as freely as possible. We have the skills and technology to make human-built environments that can coexist with living systems. In the present work, these approaches are given the term *amphibious landscaping*. In the search for a *marine landscape architecture*, methods to transfer textures and structures from the natural rocky shore to create new geological signatures have been developed. Close-range photogrammetry is used to record local geotopes, and from this we have created 3-D models reflecting physical shoreline features. These models are refined with upscaling in mind, such as large-scale additive manufacturing to create new architectural forms for the urban intertidal. To illustrate this opportunity, a small-scale experiment of 3-D printing porcelain tiles inspired from marine creatures has been carried out. So far, the 3-D visualisation "Marine Landscape Architecture" is the farthest we have come towards making a catalogue of marine landscaping elements.

The thesis' co-creational work expands our images and consciousness of existing relations within the urban setting, including the realm undersea. This is an attempt at taking a practical approach towards the multispecies perspective, which implies to show care in the interaction between humans and non-human others. The concept of *multispecies neighbourhoods* is introduced as a strategy to make people more aware of the value of marine life as a vital part of the urban blue-green infrastructure and ecological community. The blue common is not yet acknowledged as equal to the parks and public green spaces on land. Nevertheless, many studies show that the opportunity to be close to nature in urban environments is fundamental to people's health and well-being — benefits that apply no less to the marine environment.[233] To succeed in promoting marine life in "urban deserts," there is an overall need to explore and test nature-based solutions in an adaptive manner, hence the creation of *living blue labs* as common, cross-disciplinary learning platforms are promoted. This approach provides a golden opportunity to co-develop marine neighbourhoods that meet the needs of marine life and human beings. Over time, living blue labs can potentially evolve into a solid basis for a holistic management of the urban blue commons and become arenas for a much-needed ocean literacy. The thesis offers a common language and the outline of stepwise guidelines for the entire building process from preparation and planning, to implementation and adaptation. *The marine neighbourhood toolkit* is centred around identifying limitations and finding solutions to the main constraints to human beings' connectedness to marine nature in urban sea areas and hence the possibility of coexisting with natural systems in multispecies neighbourhoods.

Ways forward

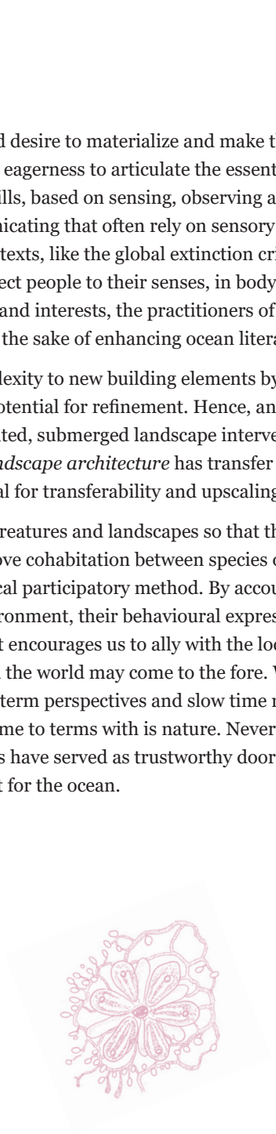
As the leading researchers within the field of coastal eco-engineering point out, this field is still in its infancy and there are many limitations and unknowns to this practice. Accordingly, the best ways of managing biodiversity and a well-functioning ecosystem is to minimize interventions and work with nature whenever possible. As with most innovative practices, we learn more from failure than from success.[234] Nature is unpredictable — and humans must learn to adapt. In this regard, my dream is to become part of a multispecies research constellation. Facilitating for marine life by means of a *marine landscape architecture* and observing the creatures' responses would form rewarding educational platforms. We should seize the momentum for change and establish locally adapted living blue-labs as an integrated part of current urban development. One way to support such implementations for building this much-needed evidence-based knowledge, which would also strengthen the basis for policy development, is to apply for the funding of long-term co-creative research.

233 (BlueHealth, 2020)
234 (Firth et al., 2020; O'Shaughnessy et al., 2020)

The artistic imagination and desire to materialize and make things happen has been a catalyst for the thesis' innovativeness — likewise the eagerness to articulate the essentials and interests of urban waterscapes. Many artists have refined unique skills, based on sensing, observing and, hence connecting the dots. They practice ways of thinking and communicating that often rely on sensory rather than intellectual apprehension. In the dissemination of complex contexts, like the global extinction crisis, this is indispensable: the power of artistic methods is the ability to connect people to their senses, in body and mind, and make the world *felt*.[235] To reach out to a broader set of people and interests, the practitioners of the arts, the natural sciences and urban development should join forces for the sake of enhancing ocean literacy.

Transferring nature's complexity to new building elements by means of digital fabrication in marine life-friendly materials has great potential for refinement. Hence, another dream in extension of this thesis is to be able to test digitally fabricated, submerged landscape interventions in urban sea areas. By breaking new ground, the thesis' *marine landscape architecture* has transfer value to other places in Norway and the world. To move forward, the potential for transferability and upscaling of the method needs further investigation.

To make space for people, creatures and landscapes so that they can reach their full potential is all about co-creativity. Aiming to improve cohabitation between species on land and undersea, I intend to start using the co-creator concept as a local participatory method. By accounting for non-human others' responses to a site and to our use of the environment, their behavioural expressions can become more present in our lives. Multispecies site development encourages us to ally with the local species diversity. Henceforth, local teams of co-creators from all around the world may come to the fore. What matters is the assembly of a dedicated community of learners. Long-term perspectives and slow time matters. Good relations matter and the partner we first and foremost must come to terms with is nature. Nevertheless, in this work, the simple qualities of being enthusiastic and curious have served as trustworthy door openers along the way — both derive from a deep fascination and respect for the ocean.



235 (Hovind, 2019)

List of engagements 2017–2020

Publishing and archiving

This compilation thesis comprises various formats, from written journal papers, an art exhibition and multi-sensory works. The below list takes you through my engagement in ocean literacy and public outreach having influenced and informed the creation of new knowledge. Pending the approval of the project, the thesis audio-visual works are published in the Research Catalogue: https://www.researchcatalogue.net/view/848167/848168 The work will be continued in the near future with the art projects “Under/sea” and “Ocean's Ears,” and in a paper co-written with Ivar Kjellmo on digital fabrication.

Teaching

Teaching was not an official part of the doctoral research fellowship. As both students and teachers have approached me underways, regarding the thesis topic, the following guidance has been given.

April 2018—July 2019: Supervising landscape architect student Jostein Rykkelid (NMBU) by co-developing a pilot in relation to his Master thesis “Vegetated rafts — a new tool for landscape architects in Norway.” The vegetated raft is currently placed on a pond within The Norwegian University of Life Sciences Campus.

June 2019—February 2020: Supervising landscape architect student Runa Tunheim (NMBU) in the course “Internship for landscape planners” (PRAK200). With me as the mentor, we worked as a close-knit team exploring, inventorying and making the thesis “edge-inventory” and the animated pilot “Landscapes with a Soul.”

June 2019: Leading the examination panel for “Lofoten Biosphere” at The Oslo School of Architecture and Design, the Tromsø Academy for Landscape and Territorial studies.

2018-2020: Supervisory meetings with a group of students at The Norwegian Theatre Academy Østfold University College March 2019, and part of the examination panel for the workshop “Scenography as Symbiosis” led by Annike Flo and Jakob Oredsson, May 15, 2020. Shorter supervisory meetings advising altogether 16 students from Norwegian University of Life Sciences, The Oslo School of Architecture and Design, The Emergence school of Leadership, University of Copenhagen respectively.

April 2020, ongoing: Supervisory meetings on artistic research with a group of Ph.D. and Master students for Professor Dragoş Gheorghiu, affiliated to The IOSUD Doctoral School National University of Arts, Bucharest.

Coastal Cleanup

Three beach clean up actions was organised as part of the fieldwork. May 5, 2018 at Kongshavn: thirteen beach cleaners between 4-70 yrs. cleared the stretch from Alna’s outlet and around the landfill (about 350 m) collecting 60 kg of plastic waste. May 4 and 5, 2019 at Kongshavn and Hovedøya respectively: fifteen people between 3-60 yrs. collected 45 kg waste.

Social media

May 19, 2018: The association Friends of Kongshavn was inaugurated Anne Beate Hovind and Elin T. Sørensen (NMBU) and followed up with establishing the Facebook Community Blog “Kongshavn Bad,” currently having 320 followers.

Ocean literacy and dissemination

The thesis reflections has been presented in various forums at different stages of the development:

During the winter and spring 2018, urban developer Anne Beate Hovind and Elin T. Sørensen (NMBU) made a series of presentations promoting awareness on the urban intertidal to HAV Eiendom, Oslo S Utvikling (OSU), Bjørvika infrastruktur and The Oslo Waterfront Planning Office respectively.

August 5-7, 2018, Anne Beate Hovind and Elin T. Sørensen (NMBU) went on a field trip to Malmö, Sweden to learn from The City of Malmö’s large-scale eelgrass restoration project. We met Michael Palmgren, founder of The Marine Education Center Malmö: https://en.smkc.se/ and Åke Hesselkrans, caseworker at The City of Malmö. We discussed the idea of making an application to Interreg Nordic on the development of a common toolkit for urban sea areas: as Copenhagen, Malmö and Oslo share similar challenges on the urban intertidal.

The summer 2018: urban developer Anne Beate Hovind and Elin T. Sørensen (NMBU) co-presentated in various contexts. August 15: A talk at “Arendalsuka”: a national arena for actors in politics, society and business. August 22: A talk at the seminar “By møter fjord — ny kraft til arkitektur, biologi og sosialt mangfold” organised by The Oslo Waterfront Planning Office.

August 29: A talk at the seminar “Bakkekontakt i Bjørvika” organised by Geir Rognlien Elgvin.

September 19, 2018: “Biologically Active Urban Covers,” talk by Elin T. Sørensen (NMBU) at “Resilient cities and climate change” organised by SLA at Oslo Urban Arena: https://www.oslourbanarena.com/program-1/2018/9/19/resilient-cities-and-climate-change-en

September 26, 2018: “Fra to verdener til ett landskap” (From two Worlds to One Landscape) talk by Elin T. Sørensen (NMBU) at CIENS breakfast seminar organised by NIVA.

January 6-11, 2019: presenting the research poster “Urban Underwater Landscape and Tidal Gardens — is it Possible to Transform Seafloor Deserts in Oslo Harbour to Underwater Oasis'?” at the International Temperate Reef Symposium (12th ITRS) in Hong Kong January 6-11, 2019, available from ResearchGate: https://www.researchgate.net/publication/340950580_Urban_underwater_landscape_and_tidal_gardens_-_is_it_possible_to_transform_seafloor_deserts_in_Oslo_Harbour_to_underwater_oasis

January 22, 2019: “Fremtidens landskap” (The Landscape of the Future), talk by Elin T. Sørensen (NMBU) for the seminar “Fremtidens landskap,” at the National Library of Norway organised by Geir Rognlien Elgvin.

January 31, 2019: “Betong og havet” (Concrete in the Sea), talk by Elin T. Sørensen (NMBU) for the Yngres Betongnettverk (YBN) annual dinner organised by Yngres Betongnettverk.

June 16, 2019: “Den blå parken” (The Blue Park), a Podcast co-created with journalist Ragna Kronstad, formerly working for Sabima: an umbrella organization for biological associations in Norway, spreading knowledge on ecological issues and propose political solutions. The Podcast series about biodiversity in Oslo was commissioned by Oslo European Green Capital 2019: https://shows.acast.com/biomangfold-oslo/episodes/den-bla-parken

September 19, 2019: “Mind the Gap — the Blue Common,” co-presentation by marine biologist Eli Rinde (NIVA) and landscape architect Elin T. Sørensen (NMBU) at the International Federation of Landscape Architects IFLA — World Congress “Common Ground” in Oslo.

February 28, 2020: Opening of the exhibition “HAV,” Norwegian BioArt Arena Vitenparken campus Ås.

Communication and public outreach

In the context of the thesis' explorative action research, engaging in public outreach proved especially vital to attitude-changing work: each article and appearance in the media has served as an introduction to the urban coastal community of the inner Oslofjord, providing valuable feedback in return. I have come to know new places and people: for example, locals have asked me to engage in specific sites, expanding both my scope of understanding and area of fieldwork.

2020

Review on the exhibition “HAV” in the journal *ArkitekturN — Tidsskrift for arkitektur, interiør og landskap*, nr. 3 2020, pp.86-91. Produced by Åshild Mienna, Grindaker landscape architecture. https://www.arkitektur-n.no/utgaver/2020/3#

Interview with Eli Rinde (NIVA) and Elin T. Sørensen (NMBU) in “Grønlikaia magasin” 2020, pp. 46-47. Produced by Rodeo Architects. https://gronlikaia.no/

Article “Døden i Oslofjorden» (Death in the Oslofjord) in the newspaper *Klassekampen* Saturday June 20, 2020. Produced by journalist Line Madsen Simenstad. https://klassekampen.no/utgave/2020-06-20/doden-i-oslofjorden

Article at forskning.no June 3, 2020. Produced by journalist Georg Mathisen on behalf of NMBU. “Dette gjør Norges første arkitekt på landskap under vann” (Norway's First Underwater Landscape Architect). https://forskning.no/arkitektur-biologi-biologisk-mangfold/dette-gjor-norges-forste-arkitekt-pa-landskap-under-vann/1690859?fbclid=IwAR1kG-IaG8pChsLL-uZEx1dZCe9jk6J9nTf80F6qelfHIDd0z1xsmqwTo4A

Feature in the newspaper VårtOslo March 24, 2020. Produced by VårtOslo/journalist Anders Høilund. “Slik er Oslo under vann, fra Frognerkilen til Alnas utløp” (This is How Oslo Looks Undersea, from Frognerkilen to Alna's Estuary). https://vartoslo.no/bydel-frogner-bydel-gamle-oslo-eli-rinde/slik-er-oslo-under-vann-fra-frognerkilen-til-alnas-utlop-se-videoen/224004

Article at forskning.no March 24, 2020. Produced by Harald B. Borchrevink on behalf of NIVA. “Slik kan fjorden ved Oslos havnepromenade bli rikere og renere” (This is how the Oslo's Inner Harbour Basin can Become Richer and Cleaner). https://forskning.no/havet-miljopolitikk-niva/slik-kan-fjorden-ved-oslos-havnepromenade-bli-rikere-og-renere/1656341

Feature at Ung forskning.no March 4, 2020. Produced by forskning.no/journalist Bror Møgster. “Bygger hus for dyr og planter under havet” (Builds Houses for Animals and Plants Undersea). https://ung.forskning.no/havet/bygger-hus-for-dyr-og-planter-under-havet/1648672

2019

Report on behalf of the Agency of Urban Environment and Oslo Waterfront Planning Office Desember 2019. Produced by Eli Rinde et al. (NIVA) and Elin T. Sørensen (NMBU). “Restoration of Biological Diversity of Oslo's Urban Sea Areas.” https://niva.brage.unit.no/niva-xmlui/handle/11250/2631547

Report on behalf of Bærum municipality October 2019. Produced by Eli Rinde (NIVA), Elin T. Sørensen (NMBU) and Trond Haraldsen (NIBIO). “Statement and recommendations on plans for establishing new landscapes at Lakseberget and Telenor-beach at Fornebu.” https://niva.brage.unit.no/niva-xmlui/handle/11250/2624215

Debate post in the newspaper Dagbladet Debatt August 14, 2019. Produced by Elin T. Sørensen (NMBU) assisted by Tove Rømo Grande (NMBU). “Debatten om Sukkerbiten er navlebeskuende” (The Debate on Sukkerbiten is Navel-gazing). https://www.dagbladet.no/kultur/debatten-om-sukkerbiten-er-navlebeskuende/71485373

Debate post in the newspaper Dagsavisen Debatt July 21, 2019, co-written by urban planner Anne Beate Hovind and Elin T. Sørensen (NMBU). Here we launch our idea of establishing a team of underwater gardeners to care for life below water in the Inner Oslofjord. “Oslo trenger en undervannsgartner” (Oslo Needs Blue Stewardship). https://www.dagsavisen.no/debatt/oslo-trenger-en-undervannsgartner-1.1557139

Article in the journal Park & anlegg nr. 2 2019, pp. 26-29, by Elin T. Sørensen (NMBU): “Den urbane fjæra som potensielt opplevelseslandskap” (The Urban Intertidal as a Potential Experiential Landscape).

Debate post at forskning.no February 13, 2019. Produced by Elin T. Sørensen (NMBU) assisted by Tove Rømo Grande (NMBU). “Skal vi få mer liv i Oslofjorden, er det ikke kunstige øyer vi trenger” (Artificial Islands aren't the Answer to Enhance Marine Diversity within the Inner Oslofjord). https://forskning.no/hav-og-fiske-kronikk-miljo/skal-vi-fa-mer-liv-i-oslofjorden-er-det-ikke-kunstige-oyer-vi-trenger/1292622

2018

Interview “Under overflaten” (Under the Surface) in the magazine Arkitektnytt. 24, 2018. Produced by Ivar Winther. https://www.arkitektnytt.no/tema/under-overflaten

Debate post at forskning.no May 5, 2018. Produced by Elin T. Sørensen (NMBU) and Morten Ellingsen (NMBU). “Hvorfor lukter det ikke skikkelig sjø ved Oslos havnepromenade?” (Why doesn't it smell like the sea along Oslo's Harbor Promenade?) https://forskning.no/havforskning-nmbu-norges-miljo-og-bio-vitenskapelige-universitet-partner/hvorfor-lukter-det-ikke-skikkelig-sjo-ved-oslos-havnepromenade/270134

Article in the journal Biolog nr. 2 2018, pp. 22-32, co-written between professor of marine biology UiO Karl Inne Ugland, professor emeritus of geology Johan Petter Nystuen (UiO) and Elin T. Sørensen (NMBU). “Utbygging i det blå” (Building Into the Blue). On building into the urban blue, and the effects of humanmade structures in the sea

Interview with marine biologist Louise Firth i Biolog in the journal Biolog nr. 2 2018, pp. 33-36. “Å bygge bro mellom biologi og prosjekteringsfagene” (Bridging Biology and the Engineering Disciplines). Interview with one of the world leading practitioners of ‘eco-engineering’

The paper “Byen — natur eller antinatur?” (The city — nature or anti-nature?) co-written between nature resource manager Dr. Heidrun A. Ullerud (UiO) and Elin T. Sørensen (NMBU) published in ArkitekturN nr. 2 2018, pp. 54-63. Testing the nature type mapping tool “Nature in Norway” (NiN) in an urban context

The paper “On Urban Hard Surfaces” by Elin T. Sørensen (NMBU) published in The Nordic Association of Architectural Research Proceeding Series 2018-1, pp. 411-441: On urban hard surfaces from the perspective of urban ecology

2017

Two polyvocal maps and soundscapes published at Freesound: an international open database of sounds that can also be used for scientific research and be integrated in third party applications. https://freesound.org/people/elinso/sounds/412124/, https://freesound.org/people/elinso/sounds/412129/ also presented at Notam: https://notam.no/elin-t-sorensen

List of figures

Preface

Pages ii-iii. Still from the video “Our Perpetual Ocean” showing the swirling flows of tens of thousands of ocean currents were captured in this scientific visualization created by NASA’s Goddard Space Flight Center in Greenbelt. The animation covers the period June 2005 to December 2007 and is based on a synthesis of a numerical model with observational data. Below: Microscope image capturing how zooplankton consume tiny fluorescent polystyrene beads. Still from the short film “Ren Kyst — got a spare afternoon?” reprinted by permission from Bo Eide & Verity White/Five Films © 2013. Both videos were shown in the art installation “Kaurene” (The Gyres) by Elin T. Sørensen, Stein Sørensen and Erle Stenberg © BONO 2014. The videos can be viewed at Research Catalogue: https://www.researchcatalogue.net/view/848167/962380

Pages viii-ix. Tidalscape for beginners: an overview of the tidalscape and its vertical zones with examples of where you find different marine habitats such as eelgrass, rockweed and filtering animals along the shoreline. These examples are relevant for this thesis’ study area in the inner Oslofjord. The wet— dry cycle takes place along a vertical emersion gradient within which the rhythmic access to air and water is caused by the action of the tides and weather. The topography determines how species settle: a steep slope narrows the tidal zone and at the same time the effect of the waves are stronger. Oppositely, a gentle slope extends the tidal zone, and the as the wave moves into shallow water it slow down. The intertidal vertical axis has four physical divisions, each with ecological differences: The spray zone is the area above the spring high tide line that is regularly splashed, but not submerged by ocean water. In the high intertidal, the surface area is flooded during the peaks of daily high tides and left dry in the stretches between the tides. This is the home for stress tolerant species such as barnacles, snails, mussels and crabs. The midlittoral zone is the intertidal zone, known also as the shoreline, extending from the spring high tide line, which is rarely inundated, to the spring low tide line, which is rarely not inundated. The sublittoral starts immediately below the midlittoral and is permanently covered with seawater. The algal dominated zone, which may extend to five meters below the low water mark, is called the infralittoral zone. Diagrams by Elin T. Sørensen © BONO 2020.

Part I

Page 2. Shaded relief map of Norwegian waters by MAREANO 2008, retrieved July 2020.

Norwegian Maritime Boundaries, map by The Norwegian Military Geographic Service Oslo, September 2012, retrieved July 2020. https://www.regjeringen.no/contentassets/1490c8d4bf9843ecb22970bdcde39d6c/20121002_fmgt_overview_norge_nordomraadene_norske_maritime_grenser_7.5m_h61xw52_p_jb_ed04_ugradert_300dpi.pdf

Page 4. Shaded relief map of the Oslofjord by MAREANO 2008, retrieved July 2020. Below: Schematic cross-section of the inner Oslofjord. In the section Bunnefjorden is aligned with Lysakerfjorden and Vestfjorden. The Drøbak Strait, about 30 km south of Oslo, has a threshold with a maximum depth of approximately 200 m. Vestfjorden’s maximum depth is 164 m and Bunnefjorden’s is 154 m. The vertical scale is exaggerated in relation to the horizontal scale. Diagram by Elin T. Sørensen © BONO 2020, based on Baalsrud & Magnusson 2002, p. 18 (fig. 3).

Page 6. The inner Oslofjord’s blue highway. The red circles show the excavated grounds facilitating the traffic lanes. The red dotted lines show the sea-lanes for the larger tourist and cargo ships and the blue dotted lines show the lanes for the local ferries. Oslo’s inner harbour basin is defined by a threshold depth of 22 m, its area being located between the islands Nakkholmen, Lindøya and Hovedøya. The deepest areas undersea extend from north of Nakkholmen to Kavringen. South of Kavringen there are areas with depths down to 29 m. There are equally deep areas by Springeren. The City of Oslo have envisioned and defined the central islands as the “Realm of the Islands” for recreation and outdoor activities. Diagram by Elin T. Sørensen © BONO 2020, based on Norconsult 2015 p. 10 (fig. 1), and the City of Oslo 2020 “Aktiv vannflate” (An Active Water Surface), pp. 10, 30.

Page 7. Bestumkilen in July 1956 and May 2019, showing the increased use of the bay as well as Hoffselva’s floodplain and estuary as a parking space for boats. Maps retrieved from norgeibilder.no, August 2019.

Page 8. Undersea mapping showing the more pristine areas by the Tisler cold-water coral reef: the largest known coral reef in sheltered waters in Europe, within the Hvaler archipelago in the Outer Hvaler National Park. Below: Heavily trawled area shown as scars on the marine plains close to the reef. Underwater recording from 2019, published by permission from Kongsberg Maritime, Sensors & Robotics partner in “Frisk Oslofjord.”

Page 10. Two examples of the proposals from the international competition addressing new harbour designs for the Port in 1897, No. 4 “Havneby af Rang” (Seaport of High Rank, unknown author), and No.5 “Nyt Land” (New Land, unknown author) which shows a channel between the bays Bestum- and Frognerkilen. Photocopied maps published by permission from the Port Authority of Oslo.

Page 12. Two examples of the proposals for the competition in 1915, No. 8 “Ekonomi” (Economy), 1. purchase contribution by the author Chief Engineer Georg Møen, Kristiania Port Authorities, and No. 9 “Hovedøen,” 3. purchase contribution by the authors Engineer B. I. Corwin and Engineer I. Lunde from Trondheim. Photocopied maps published by permission from the Port Authority of Oslo.

Page 13. Sjursøya 1919/1935. Flip animation by Elin T. Sørensen © BONO 2018 based on original photos by Anders Beer Wilse 1919/1935 published by permission from Oslo Museum.

Page 15. The inner Oslofjord fieldwork area. Map retrieved from norgeibilder.no, February 2020. Flo/Sørensen 2020.

Page 18. Polyvocal map: Frognerkilen, Frognerstranda, Kongen marina, Aker brygge — the Harbour Promenade western part — recorded October 12 and November 7, 2017.

Page 21. Stills from the flip animation “Bundebekken,” a study of the fluvial morphology of the stream’s outlet in Bonnebukta. The work is based on aerial photos from 1956, 1979, 1988, 2003, 2008, 2011, 2013, 2014, 2016, 2017 and 2018, retrieved from "Norge i bilder" February 2019.

Pages 24—25. From revisiting my childhood favourite “Who Will Comfort Toffle?”, it is Jansson's lonely Toffle — standing on a beach, contemplating amongst blue mussels and a conch against the pink night skies — who led me further in my search for ways to trigger emotional recognition of the urban seashore. Three versions of evocative landscape drama. Above: Toffle at the beach © Tove Jansson 1960 Moomin Characters TM. The contemplation of nature, whereby the landscape mirrors the viewer’s inner state in the iconic romantic painting “Wanderer Above the Sea of Fog” by Caspar David Friedrich from 1818, retrieved from Wikimedia Commons the free media repository 2020. Seduction and drama in “Star Observatory,” designed by Nicodemos and Elena K. Tsolakis of Kyriakos Tsolakis Architects. The rendering is made by MIR. Norway’s leading architectural visualizationstudio who makes portraits of unbuilt architecture. The work is reprinted by permission from MIR. and the architects.

Pages 26—27. The Fjord City from Konshavn/Grønlia in the east to Bestumkilen in the west with an urbanized shoreline of 22.3 kilometres.

New visionary proposal from Konshavn/Grønlia to Bestumkilen with a diversity-promoting amphibious tidalscape with a shoreline of 25.4 kilometres.

Pages 30—31. Once upon a time, the Bygdøy peninsula was amongst the isles of the inner Oslofjord. The name is from Norse, where bygð means an “area with houses and population” and ey “island.” In former times, this was the only inhabited islet in the inner part of Oslofjord. Later, the land was called “Ladegaardsöen,” and the bays Bestumkilen and Frognerkilen were named “The Ladegaards Fjords.” Due to vertical land motion — explained by the rise of landmasses after the lifting of the huge weight of ice sheets during the last glacial period — Bygdøy eventually became a half-island that separated the bays. One of the proposals to the design competition for the Port development of Kristiania from 1898, shows a 20-meter-wide channel across the isthmus. In this pristine landscape the engineers connected the two waterscapes by drafting an advantageous shortcut for marine transport. As stated in 1898, “A canal at this site will be invaluable for the renewal of the inner part of the Frognerkilen bay.” The pictures above show stills from “Landscapes with a Soul” based upon maps from 1624, 1856, 1881, 1898, 1956, overlain with the Fjord City's present layout from 2019, and the predicted storm surge data for the year 2090. The sequence covers the fieldwork areas from Lysakerelva in the west to Filipstad and Tjuvholmen towards the city centre.

The Bygdøy peninsula is depicted in the map “Ladegaardsöen” from 1881, showing how the isle joins the mainland by a narrow piece of land. The isthmus was called “Tyskerstrand” or “Stranda,” meaning beach. It is easy to imagine this area as a wetland and soft bottom habitat. The Bygdøy Channel reappears in several proposals from the next international ideas competition in 1915 and in later masterplans as well — but it was never realized. If we look 70 years ahead in time — at the 1000 years storm surge prediction for 2090 — the two bays and their rivers clearly appear as one flooding area: overlaying the storm surge data with the historical maps and the present-day layout reveal an alignment between the original shoreland and today’s flood-prone landscape. The area calls for shoreline softening: implying the implementation of soft edges, wetlands and blue forests providing for a climate proof urban bluescape. With the help of amphibious landscaping and buoyant solutions one potentially could achieve a landscape that may withstand the forces of nature. From the animated pilot by Elin T. Sørensen, assisted by Runa Tunheim © BONO 2019-2020.

Pages 32—33. The pictures show stills from “Landscapes with a Soul” from Frognerstranda: in the present-day layout, this urban beach is made from urban demolition-waste rock forming a uniform shoreline-landfill. The depictions express different weather and light phases. At the end of the sequence, a new landscape emerges with an organic shoreline formation that mimics the natural rocky shore with blue forest, seagrass meadows and re-natured riverbanks of the Frognerelva estuary. The pictures also show the Kongshavn area, today existing as an urban demolition-waste rock fill and uniform shoreline-landfill. The future vision shows a shoreline formation modelled on nature with blue forests and re-natured riverbanks of the Alna River estuary. From the animated pilot by Elin T. Sørensen, assisted by Runa Tunheim © BONO 2019-2020.

Part II

Page 36. Some examples of marine infrastructure which makes up coastal hardening and ocean sprawl. Diagram by Elin T. Sørensen © BONO 2020, based on Duarte et al. 2013, p. 95.

Geographical location of a qualitative review of 109 eco-engineering studies. The size of the circles indicates the number of studies at each location. So far there are no such studies in Norway, seen as a blue country. Diagram by Elin T. Sørensen © BONO 2020, based on Strain et al. 2018, p. 431.

Page 39. Shoreline softening and shoreline hardening. Photo from Bonnbekken’s estuary by Elin T. Sørensen 2019. Photo from Akerselva’s modified edge and channelization by Runa Tunheim 2019. Diagram by Elin T. Sørensen © BONO 2020.

Page 40. Investigating the sea area by snorkelling at Tofte, discovering a small eelgrass meadow (*Zostera marina*) and encountering a deepnosed pipefish (*Syngnathus typhle*). Underwater photos for the project “Sagene Seil” (Sagene Sails) by Sondre Ski, April 2016.

Page 42. The Palm is a constructed archipelago in the United Arab Emirates. The construction started in 2001 and is the largest artificial island in the world. The new landscape has increased the Dubai coastline by 130 percent in linear extent. Ecologically, however, it represents a poor habitat. Map retrieved from Google Earth April 2018.

Page 44. Checking a marine biological experiment in Plymouth, part of Kathryn O’Shaughnessy’s award-winning Ph.D. project “Green engineering of coastal infrastructure: a design for life,” which examines the impact of sea wall design on marine wildlife. Close-up of 3-D printed habitat design tile created by Reef Design Lab for the World Harbor Project. A small settlement surface mounted to a stone block seawall, part of James Ducker’s Master’s thesis. Photos by Elin T. Sørensen © BONO 2018.

Page 46. Layered waters, diagram by Elin T. Sørensen © BONO 2020.

Page 49. Reef builders from the collection of marine organisms assembled from the shores of the inner Oslofjord, like the tube-building annelids (*Pomatoceros triqueter*). Macro-shots by Elin T. Sørensen © BONO 2020.

Page 50. ECOncrete® prototypes placed in the sea by a technical diving team. The module’s complex surface set against the standard armour-unites cast in Portland cement. Photos by ECOncrete reprinted by permission from Shimrit Perkol-Finkel.

Page 52. A blade of sugar kelp with folds and textures providing strength and durability, like the ridges of corrugated cardboard. Sugar kelp and other kelps are photosynthetic and use their blades to collect and absorb sunlight near the ocean surface. Microscope images shot at the Imaging Centre NMBU by Elin T. Sørensen © BONO 2019.

Page 53. Sea anemones at The National Marine Aquarium in Plymouth. Photo by Elin T. Sørensen © BONO 2018.

Page 55. Cambro-Silurian imprint from Frognerstranda: cast in marine life-friendly Jesmonite marbled with red and white pigments. The pink colour is inspired by maerl, and the slab has beach stones, snail houses and shells underneath. Imprint and casting by gypsum-maker Jean Waldemar Hoff. Marine biological guidance by Eli Rinde NIVA. Photo documentation from “HAV” by Jon Gorospe. Sørensen © BONO 2020—on going.

Page 56. Blue mussel habited by crustose calcareous red algae. Microscope image shot at the Imaging Centre NMBU by Elin T. Sørensen © BONO 2019. Maerl bed at Krøttøya in Harstad, Troms. Underwater photo reprinted by permission from Eli Rinde (NIVA).

Page 58. Shaded relief map showing the latest version from the national database for seafloor elevation data. Due to the interests of National Security, the available resolution for seafloor data has a resolution of 50 by 50 meters, compared to 1 by 1 meter on land. The black space between land and seabed indicates a lack of data input and the six transects show the species mapping explored by NIVA in 2004. Diagram by Elin T. Sørensen © BONO 2019. Shaded relief map retrieved from "hoydedata.no/LaserInnsyn/," August 2019.

Page 60. Moss animals (*Bryozoa*) living on sea wrack. Scanning electron microscope (SEM) image shot at the Imaging Centre NMBU, by Lene Cecilie Hermansen and Elin T. Sørensen © BONO 2020. A contour map of one-meter equidistant based on land and the bathymetric data from the inner Oslofjord which has been made available. Map by Elin T. Sørensen © BONO 2020. Data retrieved from Geonorge NGU and Norge digitalt February 2018.

Page 62. Hovedøya’s coastline offers 5.8 km of diverse intertidal environments, like the small pocket beach. On May 18, 2018, the pocket beach was experienced and measured. The beach spatiality was mirrored into the industrial landscape in Lohavn, and the seafloor was lifted to a gently sloping beach, as shown in the illustration to the right. An action resulting in an epiphany on landscape scale, diversity and well-being factors. Illustrations by Elin T. Sørensen © BONO 2018/2020.

Page 63. Ostøya in the inner Oslofjord offers a multitude of ecological niches. If the island is scaled to 20 m2 it has a coastline of 33.9 m. In comparison, the 20 m2 artificial island “CPH-Ø1” in Copenhagen has a “coastline” of 16.9 m. It has a uniform design, except from the deciduous tree. Texture samples from Hovedøya compared to a concrete wall from Bispevika. As a rule of thumb: the steeper the structure, the smaller the extent of intertidal habitats. The steeper slope with fewer angles and irregularities the less space for marine life. Smooth surfaced and straight edges generally provide fewer living spaces. Diagrams by Elin T. Sørensen © BONO 2019.

Page 64. Post-it Note with a key question from 2017: how to transfer textures from the rocky shore and create new landscape designs in marine life-friendly materials? Moss animals (*Bryozoa*) inspiring the pattern configuration for the modular tiles and slabs, which in turn is inspired by the shelving system BUILD created by MOVISI Modular Lightweight Furniture. Example of plaster cast from Frognerstranda and the bryozoa-pattern. The making of imprints from the Cambro-Silurian rock formations at Frognerstranda. These nature-replicas represent local structures at a centimetre-scale and textures at a millimetre-scale. Imprint cast in Jesmonite and marbled with red and white pigments. Photos by Elin T. Sørensen © BONO 2017, 2018. Scanning electron microscope (SEM) image shot at the Imaging Centre NMBU 2020. Photo documentation from “HAV” by Jon Gorospe. Sørensen © BONO 2020.

Page 65. A porcelain sample placed in the basin at NIVA Research Facility Solbergstrand August 2018. Ceramist Tulla Elieson, marine biologist Eli Rinde and artist/landscape architect Elin T. Sørensen discussing ceramic glazes. Photos by Elin T. Sørensen 2018 and Karin Beate Nosterud, NTP January 2020. Rinde/Sørensen © BONO 2020.

Page 66. Photo observations from the growth trials at Solbergstrand showing young sea wrack growing on porcelain in September and October 2018 respectively. From the work process at Norwegian Technical Porcelain 2019-2020. A shrimp in a porcelain house in the saltwater aquarium at the exhibition “HAV.” Photos by Karin Beate Nosterud NTP 2020 and Elin T. Sørensen © BONO 2018-2020.

Page 66. Example of the latest high-resolution photogrammetry model with 1.911 of 1.930 aligned images of the tidalscape at Hovedøya. The pocket beach in May 2018 and Ivar Kjellmo with a digital single-lens reflex camera, kneed rubber boots and the pink thread at Hovedøya, performing close-range photogrammetry on June 24, 2019. The water level was at 37 cm above LAT between 16.30-21:30 h, with the lowest point at 28 cm around 18 h. Photos by Elin T. Sørensen © BONO 2018-2019. Examples of photogrammetry models from Sørbystranda generated in Agisoft Metashape by Ivar Maalen-Johansen (NMBU), based on Samsung Galaxy mobile shots between June-August by Elin T. Sørensen © BONO 2019.

Page 71. A creative technologist preparing for 3-D scanning of toothed wrack (*Fucus serratus*) attached to a stone in the making of a marine landscape architecture. Model of a sea wrack pillar made as a 3-D printable file. Photo and 3-D model by Ivar Kjellmo 2020.

Page 72. Concrete pillar from the Bispevika development used as a reference for the new designs: *Cambro-Silurian pillar, Maerl pillar and Sea wrack pillar*. Floating dock with windows created in modular shapes inspired by the configuration of moss animal colonies. A pontoon with a Cambro-Silurian habitat underneath. Concrete end of a dock with a Cambro-Silurian face. 3-D visualisations by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020.

Page 74. 3-D tile inspired from the tube-building annelids, and from the firing process for making the ceramic tiles by ceramist Ingjerd Aarseth. The 3-D printing process is documented by a time-lapse video included in the video "Clay works." Porcelain works in the exhibition "HAV." Photo documentation by Jon Gorospe.

Page 75. Samsung Galaxy S6 image of the original barnacle colony from Nesodden, and the photogrammetry model based on the mobile shots in the middle. Micro-landscape with acorn barnacle colonies as the basis for 3-D tiles, modelled and 3-D test-printed by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020.

Page 76. The Bispevika development to the left used as a reference for the new design. Conventional loadbearing pillars are replaced by new texturized structures and a Cambro-Silurian landscape formation placed on the concrete base of the housing quarter as a new marine landscape.

Page 77. Example of the latest high-resolution photogrammetry model. A rock pool structure for new marine neighbourhoods and the Cambro-Silurian landscape formation offering hardbottom habitats as well as depressions for soft bottom dwellers. All 3-D visualisation by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020.

Pages 78—79. A marine landscape adapted for Lakseberget in Sandvika, created by local surplus rock material and designed to facilitate for blue forest and marine neighbourhoods. The four models show examples of marine nature types and ecological functional areas such as sand and boulder habitats for shore crabs and lobsters. 3-D visualisations by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020.

Part III

Page 80. A purple sunstar (*Solaster endeca*) casually resting its arm on sugar kelp (Saccharina latissima) growing on a coralline red algae-encrusted rock. Underwater photo reprinted with permission from Pernilla Carlsson (NIVA). The motive was found in Melfjordbotn October 2008.

Page 84. Coming across Mrs. Fillyjonk from Tove Jansson's literary universe gave sudden insight into the reality of the Fjord City as a "play." In the illustration, this character appears as an astonishingly precise personification of some less sympathetic types acting within the mentioned "scenery:" she embodies narrow-mindedness, jealousy, suspicion, and scepticism towards new ideas. The artwork in the book "What Happens Next?" shows Moomin and Mymble encountering Mrs. Fillyjonk at the shore. Finding this book, I was re-introduced to Jansson's graphic style, which further influenced the thesis' landscape visualisations. Tove Jansson (1952) reprinted by permission from Cappelen damm "What Happens Next?" 2017, pp. 12-13.

Page 87. The sketch that caused trouble: in the drawing an organic shoreline formation that mimics the natural rocky shore shoreline replaces the industrial port landscape. I was curious to see what it possibly could look like if the excavated seafloor was lifted for the sake of improving the conditions for both marine life and people. To deploy rock fill material into the sea, however, is more technically challenging than on land, and thus, a costly procedure. Among other things, the risk of churning up polluted sediment is a serious environmental issue. Still, regarding the human footprint along urbanised waterfronts, I believe that previous building activity must be thoroughly re-thought and current building practice must be re-considered. Drawing by Elin T. Sørensen © BONO 2018.

Page 89. Intertidal fieldwork October 16, 2018: a marine biologist looking for marine life at Ormsund in the inner Oslofjord. The team of marine biologists, the project developer, and the landscape architect in the Bispevika building pit. Photos by Elin T. Sørensen © BONO 2018.

Page 90. Tunnelling work in Sandvika January 11, 2019: Cambro-Silurian material is especially favourable to local marine species, as the tidalscapes along the inner Oslofjord mainly consist of geological formations dominated by slate and limestone from the Cambro-Silurian period, the common term for the three geological periods Cambrian, Ordovician and Silur dating 419-541 million years ago. These geotopes are typical for the Vollen Formation that can be studied in many places in Oslo, especially west of the Akerselva and at Filipstad together the Frognerkilen Formation. Photo by Elin T. Sørensen © BONO 2019.

Appendix II

Page 184. Properties of eelgrass (*Zostera marina*). Diagram by Elin T. Sørensen © BONO 2018: Underwater photo of eelgrass with nudibranch and hydroid by Eli Rinde (NIVA). Photos of swans and microscope images of eelgrass by Elin T . Sørensen. The diagram is based on figure in "Seagrass" by The Department of Water and Environmental Regulation, Australia and Ugarelli et al. 2017, p. 13 (fig. 1).

Page 186. Blue mussels often form aggregations, attaching to each other with strong silky byssus threads. Tidal pool at Hovedøya. Photos by Elin T. Sørensen © BONO 2018/2019.

Page 188. The planned artificial island "Friluftsøya" in Lysakerfjorden. Diagram by Elin T. Sørensen © BONO 2019 based on The Norwegian Geotechnical Institute (NGI) Technical Report, November 4 and aerial maps from Google 2019.

Page 190. Example of wall zonation for a moss tapestry for a fluvial retention wall. Diagram by Elin T. Sørensen © BONO 2017.

Page 192. The shipworm's (*Teredinidae*) valves. Shipworms are notorious for boring into, and commonly eventually destroying, wood that is immersed in sea water. A wood piece after being submerged four months in the inner Oslofjord. Microscope photo and photo reprinted by permission from Andreas Treu (NIBIO). Photo of shipworms inside a sliced wood piece from Alchetron Free Social Encyclopaedia for the World.

Page 194. Bestumkilen 1956/2019 including the 2090 high water line: an area with potential for an amphibious tidalscape. River morphology and riverbed material transport with step-pool cascade, wandering channels and braided channels. Hand-drawn sketches by Elin T. Sørensen © BONO 2020, informed by Church (2006), based on the concept of Mollard (1973) and Schumm (1985). "Bed Material Transport and the Morphology of Alluvial River Channels," p. 330 (fig. 2) in Annual Review of Earth and Planetary Sciences.

Page 198. Stills from "Landscapes with a Soul," showing Frognerkilen in 1881 with a soft shoreline and the wetland area "Tyskerstrand." A proposed amphibious tidalscape with wetland, blue forests and the Frognerelva reopened. From the animated pilot by Elin T. Sørensen, assisted by Runa Tunheim © BONO 2019-2020.

Page 201cc. Elin T. Sørensen in the tidalscape. Photo by William Olsson 2019.

References

References are listed in alphabetical order by the last name of the first author. The author's full name is used, with the surname of the first author highlighted in bold. For classic books, the original year of publication is mentioned first, thereafter the year of the republished book, for example: Leon Battista **Alberti** (1452/1988). *On the Art of Building in Ten Books,* MIT Press Ltd.

Khaled **Abdelsalam** & Ahmed Abdelhalim (2008). Influence of colour of substratum on the marine fouling communities at the Eastern Harbour (Alexandria, Egypt). *Egyptian Journal of Aquatic Research*, 34 (1): 126-143.

James S. **Aber**, Irene Marzolff and Johannes B. Ries (2019). Chapter 3 — Photogrammetry (pp. 19-38). In James S. Aber, I. M., Susan E.W. Aber (ed.) *Small-Format Aerial Photography. Principles, Techniques and Geoscience Applications*, p. 394: Elsevier 2019.

Aftenposten. (1922). Loelv-tunnelen under Ekeberg nærmer sig sin fuldførelse. Aftenposten newspaper, Tuesday September 5, 1922.

Leon Battista **Alberti** (1452/1988). *On the Art of Building in Ten Books*: MIT Press Ltd. Translated by Joseph Rykwert with Neil Leach & Robert Tavernor.

Bård **Amundsen** (2020). As many as 200.000 coral reefs off Norway. Translated by Nancy Bazilchuk. Available at: https://sciencenorway.no/biodiversity-coral-reefs-ecosystem/as-many-as-200000-coral-reefs-off-norway/1613170 (accessed: April 20, 2020).

Marc B. **Anglès d'Auriac**, Line Le Gall, Viviana Peña, Jason M. Hall-Spencer, Robert S. Steneck, Stein Fredriksen, Janne Gitmark, Hartvig Christie, Vivian Husa, Ellen Sofie Grefsrud and Eli Rinde (2019). Efficient coralline algal psbA mini barcoding and High Resolution Melt (HRM) analysis using a simple custom DNA preparation. *Scientific Reports* 9 (Article number: 578, 2019). DOI: https://doi.org/10.1038/s41598-018-36998-6

Ard Innovation. (2020). About Ard Innovation: Ard Innovation. Available at: https://ardinnovation.no/about-ard/ (accessed: June 2, 2020).

Hannah **Arendt** (1958/1998). *The Human Condition*: University of Chicago Press, 1998.

Vidar **Asheim** (1978). *Kulturlandskapets historie*: Universitetsforlaget 1978.

Venke **Aure** (2020). Exploring Eco-social Art Strategiesto Expand Onto-epistemological and Methodological Positions in Qualitative Research. In Bergaust, Smite & Silina [Editors] vol. 18 *Oslofjord Ecologies. Artistic Research on Environmental and Social Sustainability*, pp. 135-152: Acoustic Space.

Kjell **Baalsrud** & Jan Magnusson (2002). *Indre Oslofjord natur og miljø*. Oslo: Fagrådet for Indre Oslofjord.

Gaston **Bachelard** (1983/1999). *Water and Dreams: An Essay on the Imagination of Matter*: Bachelard Translation Series. Translated by Edith R. Farrell: Dallas Inst Humanities & Culture; 3rd edition (March 15, 1999).

Marcello **Barbieri** (2008). Biosemiotics: a new understanding of life. *Naturwissenschaften*, 95 (7): 577-599. https://link.springer.com/article/10.1007/s00114-008-0368-x

Giorgio **Bavestrello**, Carlo Nike Bianchi, Barbara Calcinai, Riccardo Cattaneo-Vietti, Carlo Cerrano, Carla Morri, Stefania Puce & Michele Sarà (2000). Bio-mineralogy as a structuring factor for marine epibenthic communities. *Marine Ecology Progress Series*, 193: 241-249. https://www.int-res.com/articles/meps/193/m193p241.pdf

Kristin **Bergaust**, Rasa Smite and Daina Silina (2020) [Editors]. *Oslofjord Ecologies. Artistic Research on Environmental and Social Sustainability*. Renewable Futures series. Open Access Publication., vol. 18: Acoustic Space. Available at: http://rixc.org/en/acousticspace/

Marcia **Bjornerud** (2018). *Timefulness: How Thinking Like a Geologist Can Help Save the World. Why an awareness of Earth's temporal rhythms is critical to our planetary survival*. Earth Science: Princeton University Press.

BlueHealth. (2020). The BlueHealth project has received funding from the European Union's Horizon 2020 research and innovation programme. The programme involves specialists from countries across the EU and runs from January 2016 to June 2020. Available at: https://bluehealth2020.eu/ (accessed: January 3, 2020).

Katrin **Bohn**, Louise B. Firth, Richard C. Thompson, Simon P. G. Hoggart & Stephen J. Hawkins (2013a). Eco-engineering of artificial coastal structures to reduce their impact on the surrounding environment: An illustrated guide. *Urbane* (Urban Research on Biodiversity on Artificial and Natural coastal Environments: Enhancing biodiversity by sensitive design): 9. https://urbaneproject.org/project

Katrin **Bohn**, Louise B. Firth, Richard C. Thompson, Simon P. G. Hoggart & Stephen J. Hawkins (2013b). Management of biodiversity in disused docks – The case study of the Liverpool Docks. *Urbane* (Urban Research on Biodiversity on Artificial and Natural coastal Environments: Enhancing biodiversity by sensitive design): 8. https://urbaneproject.org/project

Johan **Borgen** (1966). *Barndommens rike*. Gyldendal Norsk Forlag 1966.

Bougnères, Kjellmo & Sørensen (2020). Professional dialogues between the 3-D experts François Bougnères and Ivar Kjellmo, and landscape architect Elin T. Sørensen regarding the project "The Abalone Toolkit" (2020-2022).

Ellen **Braae**, Lisa Diedrich & Gini Lee (2013). *The Travelling Transect: Capturing Island Dynamics, Relationships and Atmospheres in the Water Landscapes of the Canaries*. Nordic Design Research Conference 2013.

Jürgen **Breuste** (2011). Ecology in Cities: Man-Made Physical Conditions. In Jari Niemelä [Editor] *Urban Ecology: Patterns, Processes, and Applications*, pp. 17-18. Oxford: Oxford University Press.

Andrew **Brown** (2014). *Art & Ecology Now*: Thames & Hudson 2014.

Richard **Buswell**, W. R. Leal de Silva, Scott Z. Jones & Justin Dirrenberger (2018). 3D printing using concrete extrusion: A roadmap for research. *Cement and Concrete Research*, 112: 37-49. DOI: https://doi.org/10.1016/j.cemconres.2018.05.006

ByBi (2019). The Pollinator Passage. Available at: http://bybi.no/the-pollinator-passage/ (accessed: October 10, 2019).

Rachel **Carson** (1937). Undersea. *Atlantic Monthly*, 78 (September): 322-325.

Rachel **Carson** (1965 /1998). *The Sense of Wonder — A Celebration of Nature for Parents and Children*: HarperCollins Publishers Inc. 1998.

Lucien **Castaing-Taylor** & Véréna Paravel (2012). *Leviathan*: An experimental film about the North American fishing industry produced at The Sensory Ethnography Lab at Harvard University.

Riccardo **Cattaneo-Vietti,** Giancarlo Albertelli, Giorgio Bavestrello, Carlo Nike Bianchi, Carlo Cerrano, Mariachiara Chiantore, Laura Gaggero, Carla Morri & Stefano Schiaparelli (2005). Can Rock Composition Affect Sublittoral Epibenthic Communities? *Marine Ecology. Blackwell Verlag, Berlin* (23): 65-77. DOI: https://doi.org/10.1111/j.1439-0485.2002.tb00008.x

Suyin **Chee**, Abdul Ghapar Othman, Yeekwang Sim, Amni Nabilah Mat Adam & Louise B. Firth (2017). Land reclamation and artificial islands: Walking the tightrope between development and conservation. *Global Ecology and Conservation*, 12 (October 2017): 80-95. DOI: https://doi.org/10.1016/j.gecco.2017.08.005

Hartvig C. **Christie**, Stein Fredriksen, Patrik Kraufvelin & Kjell Magnus Norderhaug (2005). Tang, tareskog og ålegras som leveområde og økosystem. In Martin A. Svennin & Bror Jonsson [Editors] *Kystøkologi: Økosystemprosesser og menneskelig aktivitet. NINAs strategiske instituttprogrammer 2001-2005.Temahefte 31*, pp. 9-17: Norwegian Institute for Nature Research (NINA) https://www.nina.no/archive/nina/PppBasePdf/temahefte/031.pdf

Cineflix (Cities) Inc. in association with THIRTEEN Productions (2018). *Sinking Cities New York, Tokyo, London, Miami, Paris*: Cineflix Rights.

CMAS (2020). *CMAS International Diver Training Standards and Procedures Manual*: World Confederation of Underwater Activities CMAS. Available at: https://www.cmas.org/technique/cmas-international-diver-training-standards-alphabetical-order (accessed: June 10, 2020).

Martin A. **Coombes**, Emanuela Claudia La Marca, Larissa A. Naylor & Richard C. Thompson (2015). Getting into the groove: Opportunities to enhance the ecological value of hard coastal infrastructure using fine-scale surface textures. *Ecological Engineering*, 77 (April 2015): 314-323. DOI: https://doi.org/10.1016/j.ecoleng.2015.01.032

Stephanie **Daza** & Walter S. Gershon (2015). Beyond Ocular Inquiry: Sound, Silence, and Sonification. *Qualitative Inquiry,* 21(7) 6: 639–644. DOI: https://doi.org/10.1177/1077800414566692

Elen M. **Deming** & Simon Swaffield (2011). *Landscape Architecture Research. Landscape Architecture Research Inquiry, Strategy, Design*: John Wiley & Sons, Inc. Hoboken, New Jersey 2011.

Dana **Desonie** (2020). *Ocean Ecosystems: Hard Bottoms Biology* reference in Biology Encyclopedia. Available at: http://www.biologyreference.com/Oc-Ph/Ocean-Ecosystems-Hard-Bottoms.html (accessed: March 15, 2020).

Sandra **Díaz,** Josef Settele, Eduardo S. Brondizio, H. Ngo, Maximilien Guèze, J. Agard, A. Arneth, P. Balvanera, Kate A. Brauman, Stuart Butchart (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES secretariat, Bonn, Germany. Available at: https://www.ipbes.net/global-assessment-report-biodiversity-ecosystem-services (accessed: September, 1 2019).

Sergey **Dobretsov**, Raeid M. M. Abed & Max Teplitski (2013). Mini-review: Inhibition of biofouling by marine microorganisms. *Biofouling*, 29 (4): 423-441. DOI: https://doi.org/10.1080/08927014.2013.776042

Isabelle **Doucet** & Nel Janssens (2011). *Transdisciplinary Knowledge Production in Architecture and Urbanism: Towards Hybrid Modes of Inquiry*, vol. Volum 11: Urban and Landscape Perspectives: Springer Science & Business Media, 2011.

Carlos M. **Duarte**, Kylie A. Pitt, Cathy H. Lucas, Jennifer E. Purcell, Shin-ichi Uye, Kelly Robinson, Lucas Brotz, Mary Beth Decker, Kelly R. Sutherland, Alenka Malej, Laurence Madin, Hermes Mianzan, Josep-Maria Gili, Verónica Fuentes, Dacha Atienza, Francesc Pagés, Denise Breitburg, Jennafer Malek, William M. Graham & Robert H. Condon (2013). Is global ocean sprawl a cause of jellyfish blooms? *Frontiers in Ecology and the Environment* 11 (2): 91-97. DOI: https://doi.org/10.1890/110246

Morten **Ellingsen** (2018). *Hvorfor lukter det ikke skikkelig sjø ved Oslos havnepromenade?*: Norges miljø- og biovitenskapelige universitet (NMBU). Available at: https://forskning.no/havforskning-nmbu-norges-miljo-og-biovitenskapelige-universitet-partner/hvorfor-lukter-det-ikke-skikkelig-sjo-ved-oslos-havnepromenade/270134 (accessed: May 5, 2020).

Emporis Standards (2020). *High-rise Building (ESN 18727)*. Available at: https://www.emporis.com/building/standard/3/high-rise-building (accessed: June 19, 2020).

Elizabeth C. **English** (2009). *Amphibious foundations and the buoyant foundation project: Innovative strategies for flood-resilient-housing*. International Conference on Urban Flood Management, November 25-27, 2009, Paris, France November 2009: UNESCO-IHP & COST Action C22, "Road Map Towards a Flood Resilient Urban Environment." https://www.buoyantfoundation.org/

ETH Zürich (2019). *Concrete Choreography*: ETH Zürich Digital Building Technologies. Available at: https://dbt.arch.ethz.ch/project/concrete-choreography/ (accessed: August 19, 2019).

Etymonline (2020a). *Algae*: Etymonline Douglas Harper. Available at: https://www.etymonline.com/word/algae (accessed: April 7, 2020).

Etymonline (2020b). *Dialogue*: Etymonline Douglas Harper. Available at: https://www.etymonline.com/word/dialogue (accessed: April 7, 2020).

European Commission (2015). *Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities: Final report of the Horizon 2020 expert group on Nature-based solutions and re-naturing cities*. Luxembourg: Directorate-General for Research and Innovation. Available at: http://dx.publications.europa.eu/10.2777/765301 (accessed: 15.02. 2015).

European Commission Environment Directorate (2019). *Appendix 1—Marine Habitat types definitions. Update of "Interpretation Manual of European Union Habitats" Natura 2000 in the Marine Environment*: European Commission Environment Directorate. Available at: https://ec.europa.eu/environment/nature/natura2000/marine/docs/appendix_1_habitat.pdf (accessed: June 3, 2020).

Christopher B. **Field**, Michael J. Behrenfeld, James T. Randerson & Paul Falkowski (1998). Primary Production of the Biosphere: Integrating Terrestrial and Oceanic Components. *Science*, 281 (5374, 10 Jul 1998): 237-240. https://science.sciencemag.org/content/281/5374/237

Louise B. **Firth**, Laura Airoldi, Fabio Bulleri, Steve Challinor, Su-Yin Chee, Ally J. Evans, Mick E. Hanley, Antony M. Knights, Kathryn O'Shaughnessy, Richard C. Thompson & Stephen J. Hawkins (2020). Greening of grey infrastructure should not be used as a Trojan horse to facilitate coastal development. *Journal of Applied Ecology*: 7. DOI: https://doi.org/10.1111/1365-2664.13683

Louise B. **Firth** (2018). *Is there space for nature in the anthropocene?* In TEDx Plymouth University: April 4, 2018. Available at: https://www.youtube.com/watch?v=UY_uPfNsUGM&fbclid=IwAR2Y8FS-Gyo5kWaoNoKtvEunbOqNRWemeTUjo4VyzFrAL_OHiYCwD-taj1EQ (accessed: April 25, 2018).

Louise B. **Firth**, Antony M. Knights, Danielle Bridger, Ally J. Evans, Nova Mieszkowska, Pippa J. Moore, Nessa E. O'Connor, Emma V. Sheehan, Richard C. Thompson & Stephen J. Hawkins (2016). *Ocean sprawl: challenges and opportunities for biodiversity management in a changing world*, vol. 54. Oceanography and Marine Biology: An Annual Review: Taylor & Francis.

Louise B. **Firth**, Richard C. Thompson, Katrin Bohn, Marco Abbiati, Laura Airoldi, Tjeerd Joris Bouma, Fabio Bozzeda, Victor Ugo Ceccherelli, CMarina Antonia Colangelo, Ally Evans, Filippo Ferrario, Mick E. Hanley, Hilmar Hinz, Simon P.G. Hoggart, Juliette E. Jackson, Pippa Moore, Eilir Hedd Morgan, Shimrit Perkol-Finkel & Stephen John Hawkins (2014). Between a rock and a hard place : environmental and engineering considerations when designing coastal defence structures. *Coastal Engineering*, 87: 122-135. DOI: https://doi.org/10.1016/j.coastaleng.2013.10.015

Marius **Fiskevold** & Anne Katrine Geelmuyden (2018). *Arcadia Updated. Raising landscape awareness through analytical narratives*: Routledge. Taylor & Francis Ltd. London/New York.

Susan **Fitzer** (2019). *The world's shellfish are under threat as our oceans become more acidic*: Institute of Aquaculture, University of Stirling. The Conversation Trust (UK) Limited. Available at: https://theconversation.com/the-worlds-shellfish-are-under-threat-as-our-oceans-become-more-acidic-103868 (accessed: April 20, 2020).

Formlabs (2020). *Digital Fabrication 101*: Formlabs. Available at: https://formlabs.com/blog/digital-fabrication-101/ (accessed: June 4, 2020).

José Tomás **Franco** (2019). *There's No Good Architecture Without Daylight: How to Promote Designs Molded and Nurtured by Light*. ArchDaily. Available at: https://www.archdaily.com/929673/theres-no-good-architecture-without-daylight-how-to-promote-designs-molded-and-nurtured-by-light (accessed: April 25, 2020).

Stein **Fredriksen** (2017). Professional dialogue between Stein Fredriksen, Professor at Section for Aquatic Biology and Toxicology, The University of Oslo, and landscape architect Elin T. Sørensen, November 7, 2017.

Frisk Oslofjord (2020). *Om Frisk Oslofjord*. Available at: https://friskoslofjord.no/om-frisk-oslofjord/ (accessed: May 10, 2020).

Suzi **Gablik** (1992). *The Reenchantment of Art*. London Thames and Hudson, September 1, 1992

Suzi **Gablik** (2000). *Has Modernism Failed?* London Thames and Hudson 2000.

Government.no (2018). *The ocean nation of Norway*: Norwegian Government. Available at: https://www.regjeringen.no/en/topics/havet/the-ocean-nation-of-norway/id2609341/ (accessed: June 3, 2020).

Claire **Gwinnett** (2019). *The major source of ocean plastic pollution you've probably never heard of Environment and Energy*: The Conversation. Available at: https://theconversation.com/the-major-source-of-ocean-plastic-pollution-youve-probably-never-heard-of-111687 (accessed: January 3, 2020).

Sally D. **Hacker** & Robert S. Steneck (1990). Habitat Architecture and the Abundance and Body-Size-Dependent Habitat Selection of a Phytal Amphipod. *Ecology*, 71 (6): 2269-2285. https://www.jstor.org/stable/1938638?seq=1

Mark **Harrower** (2020). *Getting the most from animated maps*: ArcGIS StoryMaps. Available at: https://storymaps.arcgis.com/stories/0771bda76965451c9df8dd2d0759f9fd (accessed: May 3, 2020).

Stefanie **Hessler** (2018a). *Tidalectics — Imagining an Oceanic Worldview through Art and Science*. Cambridge, Massachusetts: The MIT Press Massachusetts Institute of Technology: Co-published with TBA21—Academy, Vienna, Austria. Eds. Stefanie Hessler 2018.

Stefanie **Hessler** (2018b). Tidalectics: Imagining an Oceanic Worldview through Art and Science. In *Tidalectics — Imagining an Oceanic Worldview through Art and Science*, pp. 31-80. Cambridge, Massachusetts: The MIT Press Massachusetts Institute of Technology: Co-published with TBA21—Academy, Vienna, Austria. Eds. Stefanie Hessler 2018.

Philip **Hoare** (2013). *Leviathan: the film that lays bare the apocalyptic world of fishing*. Documentary films The Guardian News & Media Limited Available at: https://www.theguardian.com/film/2013/nov/18/leviathan-fishing-film-moby-dick (accessed: November 2, 2019).

A. F. **Holland**, Anna T. Shaughnessy & Martha H. Hiegel (1987). Long-term variation in mesohaline Chesapeake Bay macrobenthos: Spatial and temporal patterns. *Estuaries*, 10 (3): 227-245. https://link.springer.com/article/10.2307%2F1351851

Torleif **Holthe** (2016). *Sneglehus*: Store norske leksikon. Available at: https://snl.no/sneglehus (accessed: February 4, 2019).

Torunn Slettemark **Hovden** (2017). *Stillehavsøstersen sprer seg kraftig i Oslofjorden*. forskning.no Norsk institutt for vannforskning (NIVA) (accessed: April 15, 2020).

Anne Beate **Hovind** (2019, September 19). *Art and participation as a driver for transformation*. Keynote speaker at The International Federation of Landscape Architects IFLA World Congress 2019 "Common Ground," Oslo 18-20 September.

Hovind & Sørensen (2017—ongoing). Professional dialogues between urban developer Anne Beate Hovind and landscape architect Elin T. Sørensen, during the period of the doctoral study 2017-2020.

Elle **Hunt** (2019). *Blue spaces: why time spent near water is the secret of happiness*: The Guardian News & Media Limited. Available at: https://www.theguardian.com/lifeandstyle/2019/nov/03/blue-space-living-near-water-good-secret-of-happiness?utm_term=Autofeed&CMP=twt_gu&utm_medium&utm_source=Twitter&fbclid=IwAR19ZxD-cHRh7Izh2egCxzWaPuXHskJEcfa7y8QiYy1Zw-2MuewA4mToxLwxg#Echobox=1572782095 (accessed: November 16, 2019).

Intergovernmental Oceanographic Commission (2020). *What is Ocean Literacy?* Ocean Literacy Portal: United Nations Educational, Scientific and Cultural Organization & Intergovernmental Oceanographic Commission. Available at: https://oceanliteracy.unesco.org/ (accessed: May 5, 2020).

International Ambiances Network (2020). *Le Réseau Ambiances | The Ambiances Network*. The International Ambiances Network. Available at: https://www.ambiances.net/ (accessed: April 2, 2020).

Tove **Jansson** (1952/2017). *Hvordan gikk det? (What happens next?)*: Mummitrollet 1. opplag 2017, oversatt av André Bjerke: Cappelen Damm.

Tove **Jansson** (1960/2017). *Hvem skal trøste knøttet? (Who Will Comfort Toffle?)*: Mummitrollet 1. opplag 2017, oversatt av André Bjerke: Cappelen Damm.

Harald **Justnes** (2016). *Eco-cement from Norwegian clay*: SINTEF. Available at: https://www.sintef.no/en/latest-news/eco-cement-from-norwegian-clay/ (accessed: May 1, 2020).

Kartverket (2019). *Se havnivå i kart – a Web Tool for Mapping Storm Surge and Sea-Level Rise*: Norwegian Mapping Authority. Available at: https://www.kartverket.no/en/sehavniva/data-pa-se-havniva/about-se-havniva-i-kart/ (accessed: June 10, 2020).

Kartverket (2020). *Se havnivå i kart (Mapping Storm Surge and Sea-Level Rise)*: Norwegian Mapping Authority. Available at: https://www.kartverket.no/en/sehavniva/visualize-sea-level/ (accessed: March 10, 2020).

Stein **Kolstø** (2013). Oslo Fjord City Course is set, making good speed! *PORTUS: the online magazine of RETE*, 25, June 2013: 5.

Stein **Kolstø** (2019, September 19). *Explore the Gap – The Blue Common*. The International Federation of Landscape Architects IFLA World Congress 2019 "Common Ground," Oslo 18-20 September.

Kourtoukov & Sørensen (2019-2020). Professional dialogues between artist and creative technologist Boris Kourtoukov and landscape architect Elin T. Sørensen, during the period of the doctoral study 2019-2020.

Petter H. **Kvadsheim**, Lise D. Sivle, Rune Roland Hansen, Hans Erik Karlsen (2017). *Effekter av menneskeskapt støy på havmiljø*. Forsvarets forskningsinstitutt. Rapport til Miljødirektoratet om kunnskapsstatus.: FFI-Rapport 17/00075. https://publications.ffi.no/nb/item/asset/dspace:2657/17-00075.pdf

Frode **Kvalø** & Elling Utvik Wammer (2018). *Bark-prosjekt Selør 3 — Flisevraket*. Arkeologisk rapport nr. 2018:2. Prosjekt nr. 2017133. Norsk Maritimt Museum. https://www.academia.edu/37208215/BARK_Fotogrammetri_Sel%C3%B8r_3_Flisevraket

Terese Moe **Leiner** & Liselotte Dick (2017). Foreword. In Leiner & Dick [Editors] *Norwegian folk tales*, pp. 5-7: Font Forlag 2017. Translated by Pat Shaw.

Aivo **Lepland**, Thorbjørn J. Andersen, Aave Lepland, Hans Peter H. Arp, Elisabeth Alve, Gijs D. Breedveld & Anders Rindby (2010). Sedimentation and chronology of heavy metal pollution in Oslo harbor, Norway. *Marine Pollution Bulletin*, 60: 1512–1522. https://pubmed.ncbi.nlm.nih.gov/20553693/

Ulla **Lind** (2015). Mo(ve)ments Beyond Representation – the student as visual ethnographer. In Göthlund, Illeris & Thrane [Editors] *EDGE: 20 essays on contemporary art education*, pp. 362-374: København: Multivers Academic.

Guillaume de **Lorris** & Jean de Meun (1230-1305?/1995). *The Romance of the Rose (Roman de la Rose)*: Third edition, and first Princeton Paperback printing, 1995. Translated and annotated by Charles Dahlberg. Princeton University Press.

Knut-Martin **Løken** & Grethe Kielland Jenssen (2016). *Kystverket sprengte ulovlig i Indre Oslofjord*: NRK https://www.nrk.no/osloogviken/kystverket-sprengte-ulovlig-i-indre-oslofjord-1.13271596

Kristen **Marhaver** (2015). *How we're growing baby corals to rebuild reefs*: Mission Blue II TED conference, October 2015. Available at: https://www.ted.com/talks/kristen_marhaver_how_we_re_growing_baby_corals_to_rebuild_reefs#t-655677 (accessed: April 25, 2018).

Benjamin **Mason**, M. Beard & Margaret Miller (2011). Coral larvae settle at a higher frequency on red surfaces. *Coral Reefs*, 30: 667-676. https://link.springer.com/article/10.1007%2Fs00338-011-0739-1

Ryan S. **McManus**, Nicholas Archibald, Sean Combera, Antony M. Knights, Richard C. Thompson & Louise B. Firth (2017). Partial replacement of cement for waste aggregates in concrete coastal and marine infrastructure: A foundation for ecological enhancement? *Ecological Engineering*, 120 (September 2018): 655-667. doi: https://doi.org/10.1016/j.ecoleng.2017.06.062.

Merriam-Webster (2020a). *Diversion*: Merriam-Webster.com Dictionary. Available at: https://www.merriam-webster.com/dictionary/diversion (accessed: April 7, 2020).

Merriam-Webster (2020b). *Epipelagic*: Merriam-Webster.com Dictionary. Available at: https://www.merriam-webster.com/dictionary/epipelagic (accessed: April 7, 2020).

Merriam-Webster (2020c). *Metonymy*: Merriam-Webster.com Dictionary. Available at: https://www.merriam-webster.com/dictionary/metonymy (accessed: April 7, 2020).

Miljødirektoratet (2007). *Kartlegging av marint biologisk mangfold*. DN-håndbok 19-2007, May 31, 2007.

Miljødirektoratet (2016). *Definisjon: Sterkt modifiserte vannforekomster (SMVF)*. Norwegian Environment Agency. Available at: https://www.vannportalen.no/tema-a-a11/1a-fysiske-endringer/2a/definisjon-smvf/ (accessed: September, 5 2018).

Geoffrey E. **Mills** (2013). *Action Research: A Guide for the Teacher Researcher*: Pearson Education, 2013.

Ministry of Climate and Environment. (Act of 19 June, 2009). *Nature Diversity Act. Chapter I Purpose and scope*. Section 1. Available at: https://www.regjeringen.no/en/dokumenter/nature-diversity-act/id570549/ (accessed: April 5, 2020).

William J. **Mitsch** & S.E. Jørgensen (1989). *Ecological Engineering: An Introduction to Ecotechnology*: John Wiley & Sons, Inc.

William J. **Mitsch** (2012). What is ecological engineering? *Ecological Engineering* (45): 5-12. DOI: https://doi.org/10.1016/j.ecoleng.2012.04.013

Even **Moland** & Jan Atle Knutsen (2018). *Oslofjorden er syk – kan den kureres?* Havforskningsinstituttet (The Institute of Marine Research IMR). Available at: https://www.hi.no/hi/nyheter/2018/desember/oslofjorden-er-syk-kan-den-kureres (accessed: January 9, 2019).

Moomin Characters. *Klovharu*. "Tove" published by: Moomin Characters Oy Ltd. Available at: https://www.tovejansson.com/eng/saari.html (accessed: April 5, 2020).

MOVISI (2020). *BUILD — a modular shelving and room divider system that adapts to your needs in minutes*: MOVISI—Modular Lightweight Furniture. Available at: https://www.hellobuild.com/ (accessed: may 15, 2020).

Joan **Mullin** (2011). Rhetoric: Writing, Reading and Producing the Visual. In Michael Biggs & Henrik Karlsson [Editors]. *The Routledge companion to research in the arts*, pp. 152-166. Part 2. London: Routledge.

NASA (2005-2007). *NASA Views Our Perpetual Ocean*: National Aeronautics and Space Administration NASA. Content Administrator, Official Brian Dunbar. Available at: https://www.nasa.gov/topics/earth/features/perpetual-ocean.html (accessed: August 2, 2013).

NOAA (2013). *Currents and Marine Life*. The NOAA Ocean Explorer Available at: National Ocean Service website https://oceanexplorer.noaa.gov/edu/learning/8_ocean_currents/activities/currents.html (accessed: February 15, 2020).

NOAA (2020a). *How far does light travel in the ocean?* Available at: National Ocean Service website https://oceanservice.noaa.gov/facts/light_travel.html (accessed: April 27, 2020).

NOAA (2020b). *What are tides?* Available at: National Ocean Service website https://oceanservice.noaa.gov/facts/tides.html (accessed: April 2, 2020).

NOAA (2020c). *What is bathymetry?* Available at: National Ocean Service website https://oceanservice.noaa.gov/facts/bathymetry.html (accessed: April 2, 2020).

NOAA (2020d). *What is the intertidal zone?* Available at: National Ocean Service website https://oceanservice.noaa.gov/facts/intertidal-zone.html (accessed: April 2, 2020).

N. **Noffke** (2012). *Geobiology: Objectives, Concepts, Perspectives*: Elsevier Science. Reprinted from Palaeogeography, Palaeoclimatology, Palaeoecology, Volume 219, Issues 1-2.

Norconsult (2015). *Konsekvensutredning for utdyping av farled indre Oslofjord: Tiltak i Bærum, Nesodden og Oslo kommuner*: Norconsult on behalf of Kystverket Sørøst https://www.kystverket.no/contentassets/1efd5214b5744bebbaf7b555299f5ebe/norconsult---konsekvensutredning-for-utdyping-av-farled-indre-oslofjord.pdf

Knut **Noreng**, Marius Kvalvik, Jan Ove Busklein, Ingrid Merete Ødegård, Corinna Susanne Clewing & Helen Kristine French (2012). *Grønne tak — Resultater fra et kunnskapsinnhentingsprosjekt*. SINTEF akademisk forlag 2012: SINTEF Byggforsk. file:///C:/Users/elinso/AppData/Local/Temp/V%20_INFO_PUB_SINTEF-Bok_pdf_SB-1.pdf

Norwegian Defence Research Establishment (2020). *HUGIN – en autonom ubåt*: Norwegian Defence Research Establishment (FFI) Available at: https://www.ffi.no/forskning/prosjekter/hugin-en-autonom-ubat (accessed: May 10, 2020).

Norwegian Environment Agency (2018). *Marine and coastal waters*. Norwegian Environment Agency: https://www.environment.no/topics/marine-and-coastal-waters/Rapport (accessed: February 6, 2019).

Johan Petter **Nystuen** (2020). *From kilometre to micrometres — land meets the sea along the coast and the shore*. A text piece for HAV — art exhibition part of the doctoral thesis: Norwegian BioArt Arena Vitenparken Campus Ås February-December 2020.

Nystuen & Sørensen (2017-2020). Professional dialogues between Professor Emeritus in Geology Johan Petter Nystuen and landscape architect Elin T. Sørensen, during the period of the doctoral study 2017-2020.

Kathryn A. **O'Shaughnessy** (2019). *Green engineering of coastal infrastructure: a design for life*: Ph.D. at The University of Plymouth Marine Eco-engineering Research Unit.

Kathryn A. **O'Shaughnessy**, Stephen J. Hawkins, Ally J. Evans, Mick E. Hanley, Paul Lunt, Richard C. Thompson, Robert A. Francis, Simon P. G. Hoggart, Pippa J. Moore, Gregorio Iglesias, David Simmonds, James Ducker & Louise B. Firth (2020). Design catalogue for eco-engineering of coastal artificial structures: a multifunctional approach for stakeholders and end-users. *Urban Ecosystems* volume 23, pp. 431–443 (2020) https://link.springer.com/article/10.1007/s11252-019-00924-z?shared-article-renderer

Gunnar **Omsted** (2018). *Internasjonale selskap vil høste sjelden norsk naturtype*: Norsk institutt for vannforskning (NIVA). Available at: https://forskning.no/havforskning-niva-partner/internasjonale-selskap-vil-hoste-sjelden-norsk-naturtype/1247826 (accessed: March 13, 2019).

Becky **Oskin** (2017). *Mariana Trench: The Deepest Depths*: Live Science. Available at: https://www.livescience.com/23387-mariana-trench.html (accessed: April 2, 2020).

Oslo Havn (2011). *Maritim kulturminneplan for Oslo havn*: Oslo Havn KF (Port of Oslo) 2011.

Oslo Havn (2013). *Renere hav, friskere luft og en grønnere by: Blågrønn strategi i Oslo Havn 2013-2033*: Oslo Havn (Port of Oslo) 2013.

Oslo kommune Byantikvaren (2008). *Strategi for vern av maritime kulturminner*: Byantikvaren i Oslo kommune (The Cultural Heritage Management Office in Oslo) 2008.

Palmgren, Hesselkrans, Hovind & Sørensen (2018). Professional dialogue between Michael Palmgren, CEO Marine Education Center Malmö, Åke Hesselkrans, caseworker at The City of Malmö, urban planner Anne Beate Hovind and landscape architect Elin T. Sørensen in Malmö, August 8, 2018.

Shimrit **Perkol-Finkel** & Ido Sella (2015). Blue is the new green – Ecological enhancement of concrete based coastal and marine infrastructure. *Ecological Engineering*, 84. 260-272. DOI: https://doi.org/10.1016/j.ecoleng.2015.09.016

Daniel **Pinson** (2004). Urban planning: an 'undisciplined' discipline? *Futures*, Volume 36 (Issue 4, May 2004): 503-513. DOI: https://doi.org/10.1016/j.futures.2003.10.008

Reef Design Lab (2019). *About Reef Design Lab: Reef Design Lab*. Available at: https://www.reefdesignlab.com/about (accessed: March 13, 2019).

Eli **Rinde** (2018). *Ruglbunn til begjær: Ønsker høsting av sjelden og sårbar marin naturtype*: Norsk institutt for vannforskning (NIVA). Available at: https://www.niva.no/nyheter/ruglbunn-til-begjaer-onsker-hosting-av-sjelden-og-sarbar-marin-naturtype (accessed: March 13, 2019).

Eli **Rinde** & Elin T. Sørensen (2019, September 19). *Mind the Gap – the Blue Common. Uncovering and Improving the Urban Blue*. The International Federation of Landscape Architects IFLA World Congress 2019 "Common Ground," Oslo 18-20 September.

Eli **Rinde**, Elin T. Sørensen & Trond Haraldsen (2019). *Anbefalinger tilknyttet planer for etablering av nye landskap ved Lakseberget og Telenor-stranda på Fornebu. En uttalelse fra et tverrfaglig fagforum opprettet av Bærum kommune (Statement and recommendations on plans for establishing new landscapes at Lakseberget and Telenor beach at Fornebu)*. Norsk institutt for vannforskning, Norges miljø- og biovitenskapelige universitet & Norsk institutt for bioøkonomi. https://niva.brage.unit.no/niva-xmlui/handle/11250/2624215

Eli **Rinde**, Elin T. Sørensen, Mats G. Walday, Camilla With Fagerli, Hartvig Christie, André Staalstrøm, Line Johanne Barkved, Henry Simmons, Harald Bonaventura Borchgrevink (2019). *Utredning av aktuelle områder og tiltak for reetablering av biologisk mangfold i Oslos havnebasseng (Restoration of biological diversity of Oslo's urban sea areas)*. Norsk institutt for vannforskning & Norges miljø- og biovitenskapelige universitet. https://niva.brage.unit.no/niva-xmlui/handle/11250/2631547

Rinde & Sørensen (2016—ongoing). Professional dialogues between marine biologist Eli Rinde and landscape architect Elin T. Sørensen, during the period of the doctoral study 2016-2020.

Jon David **Risinger** (2012). *Biologically dominated engineered coastal breakwaters*: Ph.D. Louisiana State University and Agricultural and Mechanical College. https://pdfs.semanticscholar.org/2a71/e1a195d0bf73ebded6f62a312dd738b4f227.pdf

Gustavo Q. **Romero**, Thiago Gonçalves-Souza, Camila Vieira & Julia Koricheva (2014). Ecosystem engineering effects on species diversity across ecosystems: A Meta-analysis. Biological Reviews. *Biological Reviews Early View*, 3: 1-15. DOI: https://doi.org/10.1111/brv.12138

David **Seamon** (1979/2016). *A Geography of the Lifeworld*: Routledge Revivals 1 edition (August 3, 2016).

William **Shakespeare** (1599/1993). *As You Like It*: In Jeremy Hylton [Editor]. The Complete Works of William Shakespeare: The Tech, MIT newspaper, since 1993. Available at: http://shakespeare.mit.edu/asyoulikeit/full.html (accessed: November 15, 2019).

Anne Whinston **Spirn** (1993). Deep Structure: On Process, Form, and Design in the Urban Landscape. In Thomas Møller Kristensen, Svend Erik Larsen, Per Grau Møller & Steen Estvad Petersen [Editors]. *City and Nature: Changing Relations in Time and Space*: Odense University Press (December 1, 1993).

Anne Whinston **Spirn** (2013). *Ecological Urbanism: A Framework for the Design of Resilient Cities*. https://www.academia.edu/5947134/ECOLOGICAL_URBANISM_A_FRAMEWORK_FOR_THE_DESIGN_OF_RESILIENT_CITIES

Språkrådet bokmålsordboka (2020). *Fjære*. Bokmålsordboka Universitetet i Bergen og Språkrådet © 2020. Available at: https://ordbok.uib.no/perl/ordbok.cgi?OPP=fj%C3%A6re&ant_bokmaal=5&ant_nynorsk=5&bokmaal=+&ordbok=bokmaal (accessed: April 21, 2020).

Robert Alan **Stebbins** (2001). *Exploratory Research in the Social Sciences*: SAGE Publications, Ltd. 2001.

James E. **Stembridge** Jr. (1984). Tidal range and variation. In *Beaches and Coastal Geology*, pp. 823-824. Boston, MA: Springer US.

Stenerud & Sørensen (2018). Professional dialogues between engineering geologist in the Norwegian Public Roads Administration Jørgen Stenerud and landscape architect Elin T. Sørensen, during the period of the doctoral study 2018.

Jennifer **Stitt** (2019). *For Rachel Carson, wonder was a radical state of mind*. Aeon Online Newspaper. Edited by Sam Dresser. Available at: https://aeon.co/ideas/for-rachel-carson-wonder-was-a-radical-state-of-mind (accessed: September, 20 2019).

Elisabeth M. A. **Strain**, Celia Olabarria, Mariana Mayer-Pinto, Vivian Cumbo, Rebecca L. Morris, Ana B. Bugnot, Katherine A. Dafforn, Eliza Heery, Louise B. Firth, Paul R. Brooks & Melanie J. Bishop (2018). Eco-engineering urban infrastructure for marine and coastal biodiversity: Which interventions have the greatest ecological benefit? *Journal of Applied Ecology*, 55: 426–441. DOI: https://doi.org/10.1111/1365-2664.12961

Ernest T. **Stringer** (2004). *Action Research in Education*: Pearson/Merrill/Prentice Hall.

Elin T. **Sørensen** & Hanna Bjørgaas (2016). *Sagene Seil; Landscape, ecology, coast and the marine environment*. Site analysis on behalf of Helen & Hard Architects and Anthon B Nilsen Eiendom: Urban Living Laboratory & Sweco.

Elin T. **Sørensen** (2018). Å bygge bro mellom biologi og prosjekteringsfagene: Intervju med marinbiolog Louise Firth. *Tidsskrift for Norsk Biologforening — Biolog* (2/2018): 33-36.

Elin T. **Sørensen**, Karl Inne Ugland & Johan Petter Nystuen (2018). Utbygging i det blå. *Tidsskrift for Norsk Biologforening — Biolog* (2/2018): 23-32.

Elin T. **Sørensen**, Eli Rinde, Camilla With Fagerli, Hartvig C. Christie, Mats G. Walday, Karl Jon Sørlie, Anne Beate Hovind & Sindre Langaas (2019). Urban Underwater Landscape and Tidal Gardens – is it Possible to Transform Seafloor Deserts in Oslo Harbour to Underwater Oasis? In *The 12th International Temperate Reef Symposium*. Hong Kong January 6-11, 2019 https://www.researchgate.net/publication/340950580_Urban_underwater_landscape_and_tidal_gardens_-_is_it_possible_to_transform_seafloor_deserts_in_Oslo_Harbour_to_underwater_oasis

Elin T. **Sørensen** (2020). The Blue Mussel's Voice. In Bergaust, Smite & Silina [Editors] vol. 18 *Oslofjord Ecologies. Artistic Research on Environmental and Social Sustainability*, pp. 37-62: Acoustic Space.

The American Planning Association APA (2017). *National Planning Achievement Awards 2015*. Available at: https://www.planning.org/awards/2015/achievement.htm (accessed: December 19, 2019).

The American Society of Landscape Architects ASLA (2017). *Living Breakwaters Staten Island, New York, U.S.A*. Available at: https://www.asla.org/sustainablelandscapes/breakwaters.html (accessed: December 16, 2019).

The City of Oslo Planning and Building Services & The Agency of Urban Environment. (2020). *Aktiv vannflate — en mulighetsstudie om bruk av fjorden (An active water surface)*. The City of Oslo: https://innsyn.pbe.oslo.kommune.no/saksinnsyn/showfile.asp?fileid=8902556&jno=2020012184

The Norwegian Coastal Administration (2015). *Farledsprosjektet Innseiling Oslo*. Available at: https://www.kystverket.no/innseilingoslo (accessed: June 10, 2020).

The Norwegian Directorate of Fisheries (2019). *Vern av kysttorsk i sør*. Available at: https://www.fiskeridir.no/Fritidsfiske/Vern-av-kysttorsk-i-soer (accessed: June 10, 2020).

The Norwegian Institute for Water Research NIVA (2020). *NIVA Research Facility at Solbergstrand*. Available at: https://www.niva.no/en/contact/solbergstrand-research-facility (accessed: June 5, 2020).

The Norwegian Mapping Authority Hydrographic Service (2019). *Bathymetric Data and Digital Terrain Models of the Seabed*. Available at: https://www.kartverket.no/en/data/bathymetric-data-and-DTM-of-the-Seabed/ (accessed: May 18, 2019).

The Port Authority of Kristiania (1898). *Inberetning fra Komiteen til Bedømmelse af Konkurrancepaner for Nye havne- og Bryggeralæg i Kristiania*. Kristiania J. Chr. Gundersens Bogtrykkeri 1898.

The Port Authority of Kristiania (1916). *Den Internationale Konkurranse om Præmier for Forslag til Utvidelse av Kristiania Havn*. Kristiania J. Chr. Gundersens Boktrykkeri 1916.

The Sensory Ethnography Lab (2020). *Sensory Ethnography Lab*: Harvard University. Available at: https://sel.fas.harvard.edu/ (accessed: April 2019).

The World Harbour Project (2020). *About the World Harbour Project*. Available at: http://www.worldharbourproject.org/about-us/ (accessed: April 13, 2018).

Geir **Thorsnæs** (2020). *Oslofjorden*. Store norske leksikon: Store norske leksikon. Available at: https://snl.no/Oslofjorden (accessed: June 10, 2020).

Lotta **Tiselius** (2020). *Byen er også under vandet* Arkitektforeningen. Available at: https://arkitektforeningen.dk/debat/byen-er-ogsaa-under-vandet/?fbclid=IwAR3Sg6lsZp8pUyQZwc3vHGvbLM53AbZrt-oNQ4H5ZIiIhKanRr1kRTQ6uaiE (accessed: February 26, 2020).

Piyush **Tiwari**, Ranesh Nair, Pavan Ankinapalli, Jyoti Rao, Pritika Hingorani & Manisha Gulati (2015). Living Environment. In *India's Reluctant Urbanization*, pp. 153-173: Palgrave Macmillan, London https://link.springer.com/chapter/10.1057/9781137339751_5

UK Marine (2001). *Physical gradient*. Available at: UK Marine SACs Project http://ukmpa.marinebiodiversity.org/uk_sacs/communities/intertidal-reef/ir2_1.htm (accessed: November 15. 2018).

Christy **Ullrich** (2012). *Citizen science*. Resource Library | Encyclopedic Entry: National Geographic Society Available at: https://www.nationalgeographic.org/encyclopedia/citizen-science/ (accessed: June 12, 2020).

Universitetet i Oslo (2020a). *Kambrium og Ordovicium i Oslo*: University of Oslo. Available at: http://nhm2.uio.no/norges/test/ordoviciumstrat-e.htm (accessed: May 27, 2020).

Universitetet i Oslo (2020b). *Oslos geologiske historie*: University of Oslo. Available at: http://nhm2.uio.no/norges/test/geohistorie.htm (accessed: May 27, 2020).

Thom **van Dooren** & Deborah Bird Rose (2012). Storied-places in a multispecies city. *Humanimalia: a journal of human/animal interface studies*, 3:2 (Spring 2012): 1-27 https://www.depauw.edu/humanimalia/issue%2006/pdfs/van%20dooren%20rose.pdf

Francesca **von Habsburg** (2018). A Renaissance for the Oceans. In *Tidalectics — Imagining an Oceanic Worldview through Art and Science*, pp. 7-8. Cambridge, Massachusetts: The MIT Press Massachusetts Institute of Technology: Co-published with TBA21—Academy, Vienna, Austria. Eds. Stefanie Hessler 2018.

Jakob **von Uexküll** (1934/1957). A Stroll Through the Worlds of Animals and Men: A Picture Book of Invisible Worlds. In Claire H. Schiller [Editor]. *Instinctive Behavior: The Development of a Modern Concept*, pp. 5-80: New York: International Universities Press 1957 http://www.codebiology.org/pdf/von%20Uexk%C3%83%C2%BCll%20J%20(1934)%20A%20stroll%20through%20the%20worlds%20of%20animals%20and%20men.pdf

Mats G. **Walday** & Frode Olsgard (2004). *Ny senketunnel i Bjørvika: Biologiske førundersøkelser i november 2003. Bunnforhold kartlagt med ROV og bunnfauna med grabb*. NIVA-rapport;4832.

Norwegian institute for water research 2004 https://niva.brage.unit.no/niva-xmlui/handle/11250/212427

Christopher M. **White** (2014). *Role of surface characteristics and mobile invertebrates on settlement choices and post-settlement survivorship of three scleractinian coral species*: University of Amsterdam Faculty of Science: Master Biological Sciences Track: Limnology and Oceanography.

Katelyn **Wood** (2019). *Utilizing UAS Based LiDAR Compared to Photogrammetric Techniques*. Available at: https://are-corp.com/utilizing-uas-based-lidar-compared-to-photogrammetric-techniques/ (accessed: May 18, 2020).

Worldometers (real-time monitoring/2020). *Current World Population*. Worldometers—Population—World Population. Available at: https://www.worldometers.info/world-population/ (accessed: June 17, 2020).

Zostera Experimental Network (2012). *About ZEN*. Available at: http://zenscience.org/about-zen/ (accessed: march 13, 2019).

Leikny **Øgrim** & Monica Johannesen (2014). *Action Research Introduction*. Available at: https://film.oslomet.no/action-research (accessed: March 13. 2019).

Appendix I

Contents

124—127 **HAV**

The mixed media installation “HAV” is a adapted as a digital art experience for the Research Catalogue: an international database for artistic research and a platform for the dissemination of self-published content.

129—154 **The Blue Mussel’s Voice**

The publisher’s pdf-version if the paper *The Blue Mussel’s Voice* in “Oslofjord Ecologies. Artistic Research on Environmental and Social Sustainability,” the Journal Acoustic Space. Volume No: 18/3, 2020. Renewable Futures series. An Open Access Publication. Edited by Kristin Bergaust, Rasa Smite and Daina Silina. Link to the anthology: http://rixc.org/en/acousticspace/issue/788/

Please note that corrections have been made on the pages 40-41 as typos have been found from the book’s design phase. The change is highlighted in dark blue.

155—180 **Enhancing marine biodiversity along urban shorelines: stepwise guidelines for an urban blue habitat framework, a marine neighbourhood toolkit and a common learning platform**

Post-printed version of paper prepared for submission to a peer-reviewed journal.

“HAV” evokes the spatiality of the undersea landscape: the colours and lifeforms within this hidden, fluid realm. “HAV” has many co-creators: barnacles and marine biologists, porcelain, sugar kelp, saltwater, ceramicists, crabs, clay, annelids and many more — all orchestrated by artist and landscape architect Elin T. Sørensen and staged at the Norwegian BioArt Arena NOBA, Vitenparken Campus Ås.

Curated by Annike Flo, artistic director NOBA. Open February—December 2020.

https://www.researchcatalogue.net/view/869494/869495

Detail porcelain surface for marine settlers
by Eli Rinde and Elin T. Sørensen. Photo by Annike Flo 2020.





H A V

[1] Seafloor/shelf. A floating shelving system inspired by the seafloor terrain in Lysakerfjorden. The shelves are laser-cut from poplar plywood to house treasures from my undersea expeditions, like dried and glycerine treated foliage of seaweed, various shells and dried marine animals, model building figures. On each shelf, watercolours and inks has chosen their patterns on the wood surface. The bathymetric data is created from acoustic refraction seismic mapping by the Norwegian Geotechnical Institute (NGI) on behalf of Bærum municipality 2018. The shelving system is co-developed with engineering apprentice Michael Sagen, NMBU Realtek Pilot Workshop. Variable dimension.

[2] Porcelain Works. Marine housing based on upcycling of industrial porcelain wreckage from Norwegian Technical Porcelain NTP Fredrikstad, like electrostatic precipitators and insulators. The objects are dipped in liquid porcelain and treated with various glazes mixed with popcorn and ceramic grains to create surface textures. The houses, co-created by Eli Rinde and Elin T. Sørensen, will be put out into the sea after the exhibition. Variable dimension.

[3] Undersea Fieldwork. Short glimpses into the inner Oslofjord. These 21 videos are part of a multi-sensory fieldwork comprising observations through the changing seasons 2017-2020: With expeditions taking place along the Fjord City's urban foreshore, the inner Oslofjord urban sea areas and the islands of the fjord. Soundscape Torstein Pedersen/Inspire to action. Editing Jon Gorospe. Circular projection on canvas. Variable dimension.

[4] Saltwater aquarium with animals from Drøbak Akvarium. Marine housing based on upcycled industrial porcelain wreckage, beach stones, snail houses and shells in the aquarium and on the floor. Variable dimension.

[5] Flutter/books. Risograph prints with vegetable-based inks on Munken Print Cream paper in a series of nine books. Photos by Annike Flo, Pernilla Carlsson and Eli Rinde (NIVA), Hilde-Gunn Opsahl Sorteberg (NMBU), Ioaioannis Theodorou (Sorbonne/Roscoff) and Elin T. Sørensen. Concept Annike Flo. Layout Annike Flo and Elin T. Sørensen. Riso-print Camilla Skibrek.

[6] A colony of 3-D printed tiles inspired by tube-building annelids. Porcelain tiles on floating shelves, tube-building annelids (*Pomatoceros triqueter*), model building figures, video works on two iPads and a screen. 3-D models and visualization by Ivar Kjellmo. 3D printing by Boris Kourtoukov. Variable dimension.

[7] Cambro-Silurian imprints. Textured mooring cast in Jesmonite coloured with pink pigment inspired by maerl. The mooring is attached to a Bladderwrack/signal buoy, cast in Jesmonite coloured with yellow pigment, modelled by Noshin Naseri-Lordejani, Jean W. Hoff and Elin T. Sørensen. Slabs with Cambro-Silurian texture, hemp rope, upcycled industrial porcelain wreckage, beach stones, snail houses and shells. Variable dimension.

[In the exhibition entry hall, and not included in the above installation overview]

The Co-creators. In the entry hall, you meet the exhibitions co-creators. In a play with the classification system of living things, each is introduced with a profile picture and name. Inkjet printing on Munken Print Cream paper. Layout Annike Flo, Kine Fagerheim and Elin T. Sørensen. Text by Elise Matilde Malik and Sørensen. Variable dimension.

Zostera Neighbourhood. Dried field samples of eelgrass (*Zostera marina*) with tunicate (*Ciona*) and Moss animals (*Bryozoa*) on the leaves. Felt-tip-pen drawings of people by William Olsson-Tanding and Elin T. Sørensen. Pressed flower craft on Hanemüller paper. Oak frame with Artglass 85.5 x 114 cm. Three scooters picked up from the inner Oslofjord with settlements of marine organisms.

The Blue Mussel's Voice

ELIN T. SØRENSEN
Norwegian University of Life Sciences (NMBU)

ABSTRACT
Globally, marine ecosystems are under pressure, losing species and ecosystem functions. On land – along the world's renewed waterfronts, humans have removed themselves from belonging to the sea. So far, the tendency in Norway is a development based on human interests. An alternative approach is to embrace the interests of other species, including the marine beings in multispecies cities.
Building multispecies cities demands a questioning of the relationships between nonhuman others and urbanscapes; Such as, what does it mean to include other-than-humans as participants in shared social worlds? Yet, is it worthwhile reaching out to organisms we cannot communicate with, and that most likely do not need our presence? How can we listen to critters other than us, and how can this make sense within urban development? In seeking answers to these questions, this essay is dedicated to one small and challenged creature – the blue mussel.
To reach an understanding of the urban tidalscapes, we must go beyond earthbound senses. Possible interaction and care for blue mussels and other sea creatures, are explored through close one-on-one encounters with marine life, inspired by Rachel Carson's ethic of wonder. Moreover, in order to physically make space for life below water, a diversity-enhancing marine landscape architecture is proposed; a concept arising from artistic visions in exchange with marine biology, the tidal landscape and the sea creatures themselves.

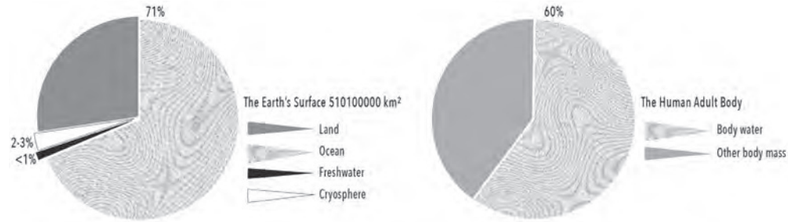
KEYWORDS: multispecies urbanism, ethic of wonder, nature as mentor, a diversity-enhancing marine landscape architecture

The sea washes the coasts – with the tides rising and falling from the gravitational interactions between the Sun, Moon, and Earth. Since the dawn of time, the tidal landscape has been a preferred place for human settlement and habitation – where the foundation for worldwide urban growth was laid. The World Ocean is an ecological zone of the greatest significance for all life on earth. Nothing less applies to the intertidal zone, where even fossil material shows us that the closer to the shore, the richer fossilized life[1].
The Ocean can also be fierce to humans and our built world. In the autumn of 2019, Hurricane Dorian led to severe coastal damage caused by strong winds, heavy rainfall and a storm surge. Thousands of homes in the Bahamas were demolished at an estimated cost of $7 billion.[2] As stated in the Washington Post: "Schools disappeared. Businesses floated away". On Abaco Island, journalists talked to a father who had

1 (Nystuen, professional dialogue, November 22, 2018)
2 (Fitz-Gibbon, 2019)



sought refuge on a roof with his five-year-old son: "Then, the father said, came the unthinkable: a powerful gust of wind sent his son tumbling across the roof and into the murky water, where he watched him disappear amid floating debris".[3] This is one of many stories from deadly natural disasters. And for those of us who haven't had to endure such events it is incomprehensible. This image strongly contrasts with the soothing influence I long for and seek in the landscape I love most of all – the tidalscape. Still to me, the vast ocean space is obscure and mysterious, and the powers of nature are frightfully immense. The world's coasts are becoming increasingly urbanized, and in about a decade it is expected that 50 percent of the global population will live within 100 km of the coast, compared to today's 40 percent.[4]
Humans must find ways to resolve the global challenges in the populated urban blue.



Water is an inorganic, transparent, tasteless, odourless, and nearly colourless chemical substance. The brain and heart contain 73 percent of water, and the lungs about 83 percent. The skin contains only 64 percent, whilst muscles and kidneys 79 percent. Even the bones are watery, with 31 percent of their weight being water. The liquid surrounding human cells has about the same salt content as seawater (0.9%). Outside us, the World Ocean covers 71 percent of the Earth's surface, and contains 97 percent of the Earth's water and 99 percent of the living space on the planet. This space is fundamental to life on Earth in a multitude of ways, for example as a source of oxygen and food, and as a driver of our climate. Yet, to most of us, this watery world is as unknown as an alien planet. Diagram by Elin T. Sørensen © BONO 2020, based on information from the Hawaii Pacific University Oceanic Institute; the U.S. Geological Survey's (USGS) Water Science School; Store Medisinske Leksikon.

The Urban Blue

Along today's developed waterfronts, humans have removed themselves from belonging to the sea. *Shoreline hardening* is a term expressing the division between the marine environment and a human-centred urbanisation. When we create our functional and rational harbour and housing areas, the effect is that the natural shore is hardened and straightened. Hence, the qualities and ecological functions of the natural rocky shore are erased.
The latest Global Assessment on Biodiversity and Ecosystem Services tells us that we are rapidly losing species and ecosystem functions. Sixty-six percent of the marine environment is "severely altered", and seventy-five percent of the land. By human actions the very foundations of our economies, livelihoods, food security, health and

3 (Horton & Ward, 2019)
4 (Small & Nicholls, 2003)

Left: Blue mussels (*Mytilus edulis*) actively filtering seawater in Lysefjorden Norway, June 2007. Reprinted by permission from Tore Strohmeier, Institute of Marine Research in Norway.

quality of life is being eroded. Some of the threatened marine habitats are formed by kelp, rockweed and seagrasses, which create underwater forests and meadows; ecosystems of the same importance as the Amazon rainforest. Due to an overload of nutrients which causes ocean darkening, and ocean warming and overfishing, these are increasingly being overgrown and replaced by non-native species. Global warming and the artificial substrates that we put into the sea are some of the factors that increase the risk of invasions by alien species. As a result, native marine species become climate refugees.[5]

Like many of the world's harbours, the former industrial Port of Oslo has been transformed into residential neighbourhoods and recreational facilities. With the first redevelopment having started in the 1980s, the project entitled Fjord City is the biggest urban development in Norwegian history and one of the largest waterfront renewals in Europe. Nevertheless, within the Fjord City improvement-actions the urban blue has been forgotten. Divers and marine biologists tend to liken the hardened shore and altered seafloor to a desert – describing the urbanised marine environment as a harsh and stressed habitat; a condition classified in European natural resource management terms as a highly modified and disturbed water body.[6] By entering this hidden and neglected landscape, I myself have experienced the marine landscape as a void – as if there is nothing underneath. Nothing but a dim no-man's land. The condition raises several questions. Can this landscape possibly be amended – can anything at all be done? Do we have a responsibility to return the disturbed seafloor and shore land to a habitable place? If so, how to battle climate change driven by human activities, the overload of nutrients and invasive species choking the local undersea creatures? How can we build up a willingness to invest in an invisible world? In seeking answers and awareness concerning the urban blue, I dedicate this text to one small, common, yet challenged creature – the blue mussel.

Why should we care for and listen to a mussel? Of the sea dwellers, neither the blue mussel, toothed wrack or bladder wrack for that sake, is included in the official reports of *threatened species* in *Norway*. Like their human co-habitants, they are commoners along the coast. Nonetheless, the blue mussel is a key species in coastal ecosystems, contributing several important functions to the sea, and during the last few years, there has been concern about the decreasing abundance of the blue mussel in the coastal waters of southern Norway and western Sweden. The Institute of Marine Research is frequently contacted by concerned people who no longer find mussels in places where they used to. Furthermore, the Norwegian Institute for Water Research has problems gathering blue mussels in southern Norway for the purpose of monitoring contaminants in Norwegian waters. The declining stocks of mussels have raised concerns amongst the marine science community in Sweden too. Indeed, all over Europe, researchers observe that mussels have changed their life and settlement habits, and this is a process that has probably been going on for decades. One of the factors responsible for these changes could be warmer summer sea surface temperatures. Another, and often related factor, is that other organisms take

5 (Díaz et al., 2019; Rinde & Sørensen, 2019)
6 (Miljødirektoratet, 2016)

over areas where the mussels were formerly settled. Yet, there are no clear answers.[7] Therefore, researchers have started to secure the future of the blue mussel and their efforts to re-create and restore mussel reefs show that it is possible to strengthen the stocks by technical solutions and human intervention.[8]



Mussels forming a mussel bed, tied together with strong silky threads.
Digital collage by Elin T. Sørensen © BONO 2019.

A Transformative Change

"In the Earth's wheel of life, the oceans provide the balance".[9] The Ocean is a common; waters connect the earth's populations, and humans depend on the ocean space as much as the kaleidoscope of life with which it churns.

Changes in the proportion of hard versus soft coastal habitats – as the natural, often sedimentary and more complex landscape features are replaced – has substantially altered the living conditions for marine species attached to coastal headlands. The biotic homogenization in the ocean space is comparable to the conspicuous deterioration of biological diversity because of urbanization on land. Regarding this, the term *ocean sprawl* addresses the proliferation of artificial structures in the sea: for example, offshore oil-rigs, wind power parks, harbours and coastal defences, aquaculture, artificial reefs, down to small buoys.[10] *Shoreline hardening* together with *ocean sprawl* are key concepts in understanding how human actions influence the blue commons. The message is that when we build something in the ocean or cover its surface, we change the environment and we take the place of somebody else.

Oslo's inner harbour has been subjected to gradual changes since people started settling the area. The extensive alterations of the shore and seafloor mainly result from the industrial development at the beginning of the 19th century and afterwards.[11] Today, the trend is to renew the industrial environments built into the sea.

7 (Mortensen, 2018)
8 (Liljeström, 2019)
9 (World Commission on Environment and Development, 1987)\
10 (Firth et al., 2016, p. 189)
11 (Oslo Havn, 2011, p. 36)

However, in most masterplans the sea is visualized as an opaque and concealing cover. Likewise, in the subsequent residential adverts, the sea appears as a glimmering surface accompanied by seductive wordings, as shown in the image below.
Field surveys along the urban sea areas of Fjord City and Oslo leave me with the impression that we have forgotten to re-scale the environment to fit human proportions and have disregarded marine creatures even more so. Often the seafloor has been excavated to make space for large cargo ships and become a landscape too deep to support photosynthesis dependent blue forests and seagrass meadows. Despite the longing and desire to live close to water, there is a knowledge gap and lack of awareness of the area between the land and sea.



The main attractions or hooks in the residential adverts tempting people to buy a property in the Fjord City are: "Do you love life by the fjord? Where the *smell* of the sea contributes to peace of mind in a busy, *everyday-life*". Photo by Elin T. Sørensen © BONO 2017.

The production of knowledge within this liminal realm clearly takes place in two separate worlds, where architects, landscape architects, gardeners and the building industry seem to be ocean illiterates. Compared to the long history of architecture and urban design examples of integrated practices where marine interests stand in the forefront are few. Even marine scientists show a lack of interest in the urban blue. As the urban ecosystem is so profoundly disturbed, this environment represents a lost cause. The tendency is not to account for the marine organisms, and the need for restoration of these habitats has so far been overlooked. Hence, the awakening of urban nature has not yet reached the sea.
As a hopeful 'bright-spot', the Global Assessment expert panel shares the optimistic view that nature can still be restored and used sustainably by means of *a transformative change* – that is also a key to meeting most other global goals. By this they suggest

a "fundamental, system-wide reorganization across technological, economic and social factors".[12] This is a wake-up call for the need to cross professional borders and join forces for a sustainable transformation of the urban blue. Urban planners, designers and marine scientists share the responsibility of restoring the marine landscape to a liveable place. Together we should take a fresh look upon this transitional space; envisioning a regaining of some of its richness.[13]
The above considerations are central to my doctoral study addressing Oslo's urban sea areas. Coastalscapes are evidently under pressure on a local and global scale, with biodiversity and human well-being at stake. Through the lens of landscape architecture, current practices for developing and treating the urban shore are explored. With the Inner Oslofjord as a fieldwork area, the study's overarching ambition is to re-establish the relationships between the land and the sea.

Multispecies Urbanism

Thom van Dooren and Deborah Bird Rose's consideration of the *multispecies city* supports the above reflections. Exploring the relationship between nonhuman others and urbanscapes, the two draw on the case of a small colony of little penguins (*Eudyptula minor*). These are small flightless seabirds inhabiting the headland of one of Sydney's busiest harbours – between the calm waters of the port and the waves of the Pacific Ocean. As part of the story we are told that these penguins connect to their hatching-spot with a high degree of "site fidelity". Another word for this is *philopatric*, literarily meaning "love of one's home". In biological terms, the phenomenon relates to how little penguins always return to their birthplace to lay eggs. The seabirds are inherently attached to a space which has been gradually altered by urbanization. Subsequently, some of the obstacles they must face in a fast-changing world are habitat loss due to development, disturbance by people such as noise, light and littering, as well as wild and domestic predators such as foxes and cats. This case is one example of the many species that must fit into human plans and spaces: Having to live in cities "on our terms, or not at all".[14] Through this, the authors present a critical view of the notion of inclusiveness, a debate that in their eyes mainly accounts for human diversity. Thus, Van Dooren & Rose call for a genuinely inclusive city – emerging from "the flourishing of as many different forms of life as possible"[15].
The concepts of the multispecies city and site fidelity changed the way I perceive a site. Suddenly, I became aware of other user groups – like the birds frequenting one of the places – again opening up new landscaping-approaches. We generally learn and know so little of nonhuman others. So, what is required to let as many different forms of life as possible flourish in the city? Looking at coexistence from a practical angle, the question I seek to find an answer to is what it really means to share space with other living beings – and how can we possibly treat them as active participants in shared social worlds?

12 (Díaz et al., 2019)
13 (Rinde & Sørensen, 2019)
14 (Van Dooren & Rose, 2012, pp. 5–10, 16)
15 (Van Dooren & Rose, 2012, p. 17)

The Community of Learners

The urbanised coastal ecosystem can probably not be restored completely to a natural state. Questions remain about how to change the current conditions to arrive at marine life friendly urbanscapes that allow the fullest potential for marine life. Changes that would benefit humans too. To break the ocean's glimmering surface, and go beyond idealising architectural narratives, the urban tidalscape is investigated by means of *explorative action research*. This is a method explained as cyclic by nature, revolving around planning, doing, seeking, and gathering. By reflection in action throughout the different phases, the researcher eventually develops a personal theory; arriving at instances of developing new knowledge as well as an emerging *community of learners*.[16]

To familiarise myself with marine life, the act of discovery started with knocking on the doors of marine biologists at the Norwegian Institute for Water Research. In order to find out how ideas such as caring for the Fjord and the possible reach for a multispecies city would be received by the planning community, I had to knock on the doors of property developers, contractors and municipality caseworkers as well. I even had to challenge my earth-bound senses by immersing myself below the surface of the sea. Over time a core learning-community has developed, consisting of me as the landscape researcher working ever more closely with a marine researcher, a project director for art and urban development, and a creative technologist. Moreover, in one of our sub-projects nearly twenty free divers took part a crowdsourced, observation and registration of the marine life in Oslo's inner harbour. Subsequently, new knowledge emerged from the responses and interactions with the landscape and people along two main trajectories.

The first trajectory is making space for the blue common by raising awareness. This is a seeding activity, aimed at opening people's minds on perspectives towards the unseen urban blue. This invisibility influences the way urban marine landscapes are treated. Henceforth, we need to go beneath the surface and include this world of the waters in our considerations. The linking of the marine and the planning communities is motivated from the desire to develop productive ways of co-creation and coexistence between urban forms and natural systems. This demands a shift from traditional human-centred urbanisation, and towards learning-by-doing across professional boundaries. To succeed, it is essential to establish a platform for shared understanding as well as a common language.

The second is to physically make space for life below the surface by articulating a marine landscape architecture; a concept arising from artistic visions in exchange with marine biology, the tidalscape and the sea creatures themselves. In seeking understanding of the architectural features of the tidalscape and for marine life, the research builds on 1:1 observation, microscope photography, and digital fabrication such as photogrammetry, 3D-visualisation and printing. The anticipated outcome is a way of building into the sea that is fundamentally different to the vertical sea walls and

16 (Ørgrim & Johannesen, 2014)

the monotonous environments that typically form the urban edge; aimed at making shared housing with liveable structures connecting land dwellers with marine life.

To Sense the World of Waters

Obviously, this realm can only be fully grasped by going beyond earth-bound senses. One-on-one encounters with the tidalscape, at different times and seasons, has been essential to the understanding of this forgotten place. Through snorkelling, I have come to know a new world of life forms and colours. Like the yellows, greens and brown hues of sea wrack and the floating motion of the clear green leaves of the eelgrass. Beside miniature rock pools on the shore, I can linger for a long time to study their wonders: Housing the tiniest of crabs less than 5 millimetres in body size yet perfectly developed – moving sideways along the rocky walls encountering transparent shrimps along the way. Even more fascinating are the miniscule barnacles using their super thin fan-like feet, sweeping plankton and detritus from the water into their mouths. All together performing a mesmerising spectacle.

My desire to see the fjord from a nonhuman perspective arose after reading Rachel Carson's (1907–1964) *Undersea essay* from 1937. Her writings took my breath away, as I was literary submerged: "To sense this world of waters known to the creatures of the sea we must shed our human perceptions of length and breadth and time and place and enter vicariously into a universe of all-pervading water".[17] This quote exemplifies Carson's excellence in bridging poetic speech with biological facts. Not surprisingly, *Undersea* is acknowledged as a pioneer-work in how, in this case, a marine biologist invites the reader to explore the World Ocean from the position of the many creatures with which we share this environment. Much in the same way *Silent Spring* (1962) voiced a roaring silence: An observed silence in nature, resulting from the use of modern pesticides – not only affected the targeted species, but biodiversity at large. Carson made people see nature from new viewpoints, and, thus, is one of the originators of ecological concerns in the 20th century.[18] In honouring her communicative skills, Margaret Atwood highlights her ability to explain science to ordinary readers in a straightforward way. Carson's love of the natural world "shines through everything she wrote", and "if you don't love a thing you won't save it" Atwood continues, pointing to empathy as an agent in developing a desire to safeguard and protect.[19] This is right in line with Carson's *ethic of wonder* that formed the basis of her ecological philosophy that she began articulating a couple of years after writing *Undersea*; an ethic which pushes our awareness towards what lies beyond ourselves, and encourages us to become receptive to the idea that we all are "linked to a vast ecological community inherently worth preserving and protecting from depletion".[20]

Undoubtedly, it is hard to grasp how, for instance, a blue mussel may be included in our world. Would it be worthwhile reaching out to an organism that we cannot

17 (Carson, 1937, p. 322)
18 (McKie, 2012)
19 (Atwood, 2012)
20 (Stitt, 2019)

talk to – and that most likely does not need our presence. With *wonder* and engaged interest we may learn to share the environment despite our differences. And to get a bit closer, it is time to familiarise ourselves with the blue mussel.

A Common Blue Mussel Spurring Imagination

One key source of inspiration for my artistic and landscape practices is delving into the realm of biology. There each specimen or phenomenon has its own astonishing story. From a myriad of possibilities, I have chosen one important inhabitant of the urban blue – the blue mussel. Blue mussels are locals in the Oslofjord, amongst others, cleaning the water to the benefit of humans and other marine neighbours. So, I will start sharing my fascination by revealing some mussel facts. *Mytilus edulis*, from Linnaeus 1758, is the common blue mussel's binomial name. In Latin *mytilus* means a sea mussel, and *edulis* commonly refers to edible plants and animals.

The Blue Mussel's Life

Blue mussels usually permanently attach themselves on rocky shores, where they can live for 18–24 years in depths varying from one to twenty meters. The animal is extraordinarily adaptable, and may withstand wide environmental fluctuations in salinity, thermal conditions, dry conditions and more.

Blue mussels have their most mobile phase during the drifting larval stage, and this time between becoming a free-swimmer and an adult lasts nearly two months. From the moment the fertilized egg metamorphoses to a free-swimming larva, it develops fan-like protrusions lining its skin – and with these the mussel filter-feeds.[21] We can only imagine the beauty of these minute hair-like organs beating rhythmically to the waves. Yet, living freely in the water column implies a risky journey, and they suffer the highest mortality rates in this period.

As a youngster, less than two centimetres in length, the mussel starts spinning its elastic silky filaments or byssus threads, shown in the illustration. These threads help the shell to stay on the floor, thus affording an effective mooring which also yields to wave energy. For example, in a situation of wave-stress, mussels may orient and re-arrange the position of their byssus in compliance to tension and load to where the most pull is experienced. These strands may stretch to 160 percent of the shell length yet retain five times the strength of the human Achilles' tendon. It is even more fascinating to learn that when the youngsters get an impulse to move, they use their byssus' as climbing ropes – extending, attaching and pulling forward across a surface.[22]

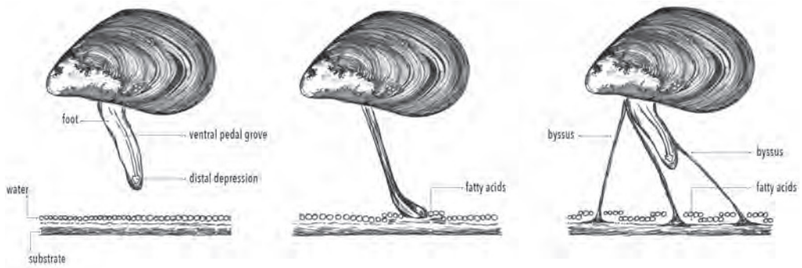
A blue mussel 'teenage-crib' is often found in small rock cavities, within threadlike, filamentous nets or among other aquatic invertebrate animals such as the Bryozoans. Presumably, due to competition, the young tend to place themselves away from

21 (Zagata et al., 2008)
22 (Brentner, 2002; Havforskningsinstituttet, 2019; Zagata et al., 2008)

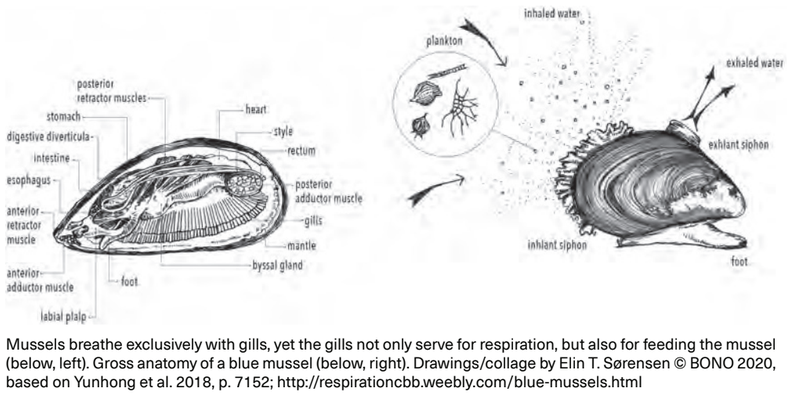
adults. The juveniles stay in one place for three weeks, and double in size, before setting themselves adrift to seek a permanent home. From the moment of settling, the mussel grows to full body-size, ranging from two to twenty centimetres, with an average of about seven. If there is a lack of firm ground, the mussels join together to form mussel beds. If knocked out of position, they can always regenerate new mooring-threads and reattach themselves. Besides, the threads function as a defence-mechanism to capture attacking molluscs. Other enemies to the mussels are starfish, crabs and snails, which limit their inhabitation of the low intertidal zone. Likewise, they are popular amongst larger marine species and seabirds – not forgetting humans. As ecological function areas, mussel-colonies bear a likeness to inclusive neighbourhoods as they are attractive to other organisms; Their shells are the building ground for encrusting algae, and the gap between the valves gives shelter to many other miniscule creatures. Mussel beds function as natural erosion control by trapping sediments and accelerating sedimentation. What is more, their irregular, flexible structure acts as a natural wave attenuator and slows down water flow. In some areas, a colony may house several thousand mussels per square meter. Blue mussel reefs are comparable to rainforests on land, and kelp forests and eelgrass meadows in the sea with respect to production rate, and all are recognized amongst the most productive natural systems on the planet.[23]

Mussels are grazers, like cows and sheep on land, and feed on the greenery of the ocean, living on a diet composed of phytoplankton, dinoflagellates, small diatoms, zoospores, various unicellular algae, bacteria and dead organic matter. When feeding, the mussel opens its protective shells to let its gills collect nutrients from the water column with small, moving hairs passing particles to its mouth. The greater the angle a shell gapes, the larger amount of water flows through the mussel, and a higher quantity of matter is extracted. On average, an adult mussel filters over a hundred litres of water a day, with up to five litres of water going through every hour before filtered water is pumped out through the exhalation opening. The blue mussels are ocean cleaners. Researchers have discovered that the mussels along the Norwegian coast are the fastest of filter-feeders. During a single day, they may clean a quantity of water corresponding to a well-filled bathtub.[24] The purifying-capacity is recognized to the extent that there exist off-the-shelf mussel-systems for water treatment and monitoring. Due to their cleaning abilities and subsequent storing of environmental toxins, the Norwegian Institute for Water Research, regularly collect mussels as part of monitoring-programs along the coast and on oil platforms. Encrusters and reef-builders such as mussels, cannot escape and must endure the environment in which they settle. This is a practical trait to the researchers: As the communities change if exposed to toxins or disruptions, their fixed position turns them into reliable monitoring-units. Eventually, the most sensitive species are lost, whilst the more robust remain.[25]

23 (Brentner, 2002; Christie et al., 2005; Havforskningsinstituttet, 2019)
24 (Havforskningsinstituttet, 2019; Robson et al., 2010; Zagata et al., 2008)
25 (Rinde, professional dialogue, April 2019)



Schematic drawings of the process of the mussel's thread formation on a hard surface



Mussels breathe exclusively with gills, yet the gills not only serve for respiration, but also for feeding the mussel (below, left). Gross anatomy of a blue mussel (below, right). Drawings/collage by Elin T. Sørensen © BONO 2020, based on Yunhong et al. 2018, p. 7152; http://respirationcbb.weebly.com/blue-mussels.html

The Blue Pastures

Mussel-farming represents highly sustainable food production. No manufactured animal feed or medication is required, as the shells feed on algae at the base of the food chain – and after one to two years, the mussels reach a marketable size. Mussel harvesting has a long history. Shell debris has been discovered in kitchen middens 10,000 years back in time, at the dawn of agriculture in the "New Stone Age". From then on, the mussel was picked from wild beds along the European coasts, utilized as food, fish bait and soil-fertilizer. Later, mussel-aquaculture was established for the sake of storage and to deliver reliable fishery products. Despite this, aqua-farming development often resulted in overfishing the natural beds, creating a need to overcome crashed populations. One innovation, dating back to the 13th century, was the French intertidal wooden-pole culture named "bouchots". During the 19th century this design-intervention spread along the entire French-Atlantic coastline, whilst in Northern Europe, a subtidal culture with bottom culture plots emerged. At the turn of the 1970s, new technological developments with a suspended longline rope culture streamlined the mussel-industry, with the keeping of wild beds for the supply of juveniles.

The blue mussel is a real cosmopolitan, thriving in most of the world's biogeographic regions. This has led to the introduction of blue mussels outside its native habitat, that together with technology transfer has expanded its cultivation. Today, China has become the world's largest producer. In Europe, Spain is in the lead, even though the potential of Norwegian waters is the greatest in Europe in terms of production. Still, some significant challenges need to be considered before Norwegian mussel-cultivation becomes economically sustainable.[26]

The Blue Mussle – a "technical" Genius

"My dream is to create – with the help of what we learn from byssus threads – self-healing materials in an environmentally friendly process that have similar physical properties..." Dr. Matt Harrington, Max Planck Institute of Colloids and Interfaces[27]

Byssal threads have caused excitement among material scientists. The mussel's silky filaments are produced in the mollusc's foot, from which the attachment fibres are spun within a fine groove. At the end of each thread is a small adhesive disc that allows the mussel to cling to hard surfaces, considered an unparalleled ability to adhere to structures undersea. Now, researchers at the Max Planck Institute, have found that these attachment-fibres stick to a surface better than any synthetic underwater glue. The study shows that many steps in the spinning-process are autonomous, without any active involvement from the mussel. This may reveal new insights on the technicalities of the assembly of polymers into more complex structures: "The biopolymer that forms the core of the thread is extremely tough and also heals itself when damaged. The cuticle of the thread is as hard as the epoxide resin used to manufacture printed circuit boards but is still highly extensible."[28] Their study promotes the blue mussel as a potential guide for developing advanced materials of biomedical and industrial relevance, for example, an environmentally friendly production of bioplastics based on biogenic high-performance polymers.

A Mussel Choir

Could art help us to come closer to mussel-ness? This is the intention behind the MUSSELxCHOIR, where other species' expressions are investigated artistically for the sake of co-creating a better future. In short, this artwork merges biological life and sound technology to convey new meaning. A choral society of mussels has performed at the Venice Architectural Biennale, in galleries and outdoors in Melbourne and New York, orchestrated by Natalie Jeremijenko, whose background includes studies in fine arts, biochemistry, physics, neuroscience and precision engineering.
As mentioned above, the blue mussels clean water and their physical responses indicate water quality, as they literally "shut-up" if exposed to a certain degree of pollution. To capture this, Jeremijenko instrumented the shells with sensors to collect data on the gap angles as the creatures open and close their valves. This

26 (Goulletquer, 2004; Havforskningsinstituttet, 2019)
27 (Max Planck Society, 2017, p. 3)
28 (Max Planck Society, 2017, p. 1)

data was converted into sound signals before eventually being refined into the mussel-recordings. The composition was further elaborated by making the pitch correspond to the depths in the water column where the mussels had settled. Finally, the tonalities were programmed to play a version of the tune "Daisy Bell (Bicycle Built for Two)".

To offer a bit of context, the 1892 pop-song "Daisy Bell" is an early example of a song that was recreated by speech synthesis or the artificial production of human speech. As a fun fact, this song was performed by HAL 9000, who is the spacecraft computer with machine intelligence in the seminal Stanley Kubrick sci-fi film "2001: A Space Odyssey" from 1968.[29] In my interpretation, Jeremijenko's artistic thinking adds new layers of context and understanding to scientific data-collection methods. Moreover, she enables us to listen to creatures normally unheard. The artist plays with technology, such as scientific instrumental precision analysis and the notion of artificial intelligence. However, concepts such as *intelligence* and *precision* are carried over to the natural world. In this way, the artist builds awareness of the capacity of mussels, and their potential role as active participants in our world. According to her, statistics shown in a graphical data representation provide insufficient readings of dynamic, complex, unpredictable urban ecosystems. In comparison, mussels perform with a legibility and honesty that embody far broader ranges than instrumental readings – by example a pH-sample. In general, the artist argues, the responses of nonhumans can help us understand the environment in ways unknown to us, and even more exactly than scientific recordings. As Jeremijenko puts it, "mussels have a higher standard of evidence, a higher literacy, and they're integrating over many more parameters".[30]

The artwork inspires critical thinking towards our relationship with nature by pointing at the wisdom, if we may say so, inherent in ecosystems – understood as the "complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space".[31] Unarguable, Humankind is part of this complex but, regrettably, this perspective is neither particularly debated nor visible within the field of urban planning and design, and in the way the urban edge meets the sea.

Jeremijenko's choral society of mussels is part of an overarching art project called *Unshoreline*. The title resounds with the aforementioned concept of *shoreline hardening* – expressing the division between marine environments and urbanisation and, thus, the removal from the rocky shore of qualities and its inherent ecological functions.

I read the *Unshoreline* artwork to critically comment upon natural systems versus human-made environments. By reflecting upon the work-context, Jeremijenko states that all the cities' inhabitants bear the risk of how the public infrastructure is created. As large-scale infrastructure systems run on correspondingly large budgets, the design directly affects the public purse. Thus, urban renewal is a hugely public

29 (Hannah, 2017)
30 (Hannah, 2017, pp. 207–209, 211–212)
31 (Encyclopædia Britannica, 2019)

issue, and at the same time represents a socialized risk. On the other hand, large-scale constructions, such as sea walls, are built to protect the citizens from natural forces. Unlike hard-edge sea walls, the multifunctional mussel beds absorb energy in the water masses. Hence, Jeremijenko posed the rhetorical question of whether man-built seawalls improve water quality or add any other environmental benefits. In her imagination, these neighbourhoods of the blue form adaptable "mega-metropolises". Metropolis being a precise analogy, as mussel reefs may house thousands of individuals, sometimes representing dozens of species all living in one place.

Jeremijenko suggests that designing with natural systems is neither part of the traditional engineering companies' mind-set nor competence portfolio. To be explicit about who benefits from the environments we design, and to make sure there actually is a shared benefit is as a huge political responsibility. The artist claims there is a lack of recognition towards the paradigm shift that acknowledges that we cannot design with force and mass. As she put it, "we have to design with buoyancy and tension, with living systems".[32] This corresponds to findings presented in the *Sinking Cities* TV-documentary, which shared insights on how five global cities are coming to grips with the effects of extreme weather and rising seas. To mitigate these challenges, there is unanimous agreement upon infrastructure and engineering that are adaptive, encouraging the development of flexible building structures that yield rather than resist nature forces.[33]

To share existence with the mussel, or any organism that is very different from us, one must invest in understanding the creature's responses to the environment. Regarding the participation of nonhuman others in urban planning, we can ask to what degree Jeremijenko's artwork brings us further. She clearly builds on knowledge that is recognized within the marine research community, where mussels already participate in monitoring-programs to reveal environmental pollution. Nonetheless, Jeremijenko's choral society of mussels exemplifies how artistic actions may offer new ways of gathering and disseminating knowledge. The artist invites people to get to know the mussels as responsive organisms which we stand with in a mutual relationship, thus opening the minds of the larger audience to what it could mean to invite mussels into our lives, and inspiring a *multi-voiced literacy*.

The philosopher Mikhail Bakhtin (1895–1975) writes about a *dialogic imagination* coming to life as a "many-voiced" expression. During the *event of exchange*, the different voices combine, resulting in a dialogic sense of truth. The word "event" was important to Bakhtin. In Russian the root of this word relates to "existence" or "being". In a more literal form, it can be interpreted as "shared existence or being with another".[34] By this perspective, any understanding occurs through responses, and through listening and speaking. In this way, various points of view, conceptual horizons, and different social "languages" come to interact with one another within a living context of exchange.[35] A dialogic imagination might be a tool we can use to

32 (Hannah, 2017, pp. 202, 207, 213–214, 216)
33 (Cineflix (Cities) Inc. in association with THIRTEEN Productions, 2018)
34 (Bakhtin, 1963/1984, p. 6)
35 (Bakhtin, 1982; Bakhtin, 1986; Irvine, 2004)

include different life forms in our world, and thus a strategy relevant to place-making between the land and sea. In campaigning for the creation of better housing standards for others, the recognition of, for instance, the mussel's far-reaching abilities is an obvious asset. For example, to help us come closer to nature, Jeremijenko suggests setting up situations from which we can read the signs of (wild)life in the urbanscape; a proposal directly related to the inclusion of nonhumans as participants in designing our environmental commons.[36]

Additional perspectives on dialogic imaginings across mental, cultural and physical borders are offered in the anthology *Tidalectics – imagining an oceanic worldview through art and science*. Here, the tidal landscape is brought forth as a contact-zone analogous to "social spaces where cultures meet, clash, and grapple with each other."[37] As coastal landscapes enable exchanges between ecosystems, as well as mentalities and fields of knowledge – they are places from which new knowledge grows. Against this fluid backdrop, artistic practices are thought to produce a much-needed porosity, wherein different views can inform one another and co-exist.[38] In contrast to the interchanging coastal ecotones, disciplinary divisions are compared to the artificial lines of i.e. national boundaries. The traditional divisions between professions often block the exchange of information and the development of common understanding between people. To go beyond this, art is proposed as an arena where people can form new ties. Stefanie Hessler, the anthology editor, suggests that the artistic drive towards entering the unknown and testing boundaries can inspire an "*undisciplined*" mindset much needed for real interaction to take place.[39]

Undisciplined Co-creation

Whilst Jeremijenko's *unshoreline* refers to removal from nature, I understand *undisciplined*, to stand for letting go of disciplinary assumptions, know-it-all, and siloed mentalities – all standing in the way for productive co-creation. A deep professional collaboration requires the ability to set oneself aside and to be receptive to the other – that is making space for otherness. Hence, these *un*-words encircle the work I stand amidst, seeking to bridge architecture and biology for enhancing urban hardscapes for the pleasure of people as well as marine creatures.

Stepping into the realms of others can be accomplished by changing from the position of operating as an expert to becoming a beginner with respect to the question at hand. This in turn, requires patience and trust – and ultimately, the acceptance of results that none of the participants may have predicted. Thus, all parties must give up their preconceived notions along the way. During my action research process, it has become clear to me that deeper professional understandings come from producing knowledge together – over time. By sharing experiences while thinking and doing together, the co-creators become familiar with each other's ways of

36 (Hannah, 2017, p. 217)
37 (Pratt, 1991, p. 33)
38 (Von Habsburg, 2018, p. 8)
39 (Hessler, 2018, p. 32)

working and thus develop experiential ties that may eventually become a professional friendship. Here, the nuance added by 'friendship' opens up responsiveness and interdependencies.

Designing together is essentially different to what is still a common practice within the planning community, wherein each field delivers separate contributions in accordance with urban planning checklists. Within *undisciplined co-creation* the parts need to *un-learn* in order to build new *collaborative* knowledge. Yet, in the hasty world of urban development, to dissolve divisions and wait for people to loosen up to undisciplined co-work may be a utopian dream; even more so to include mussels as equal participants in the planning processes. Nevertheless, from undisciplined co-creation new conceptual horizons may arise, which at best can lead to innovation.

Being With Nonhuman Others

The activation of nature in urban development **is** clearly linked to making space for nonhuman others. Yet, how likely is it for us to include nonhuman others on the participant-list in decision-making processes, and to take the trouble to see the world from, for example, a blue mussel's perspective? There is a fair chance that such propositions would be perceived as naïve, and even silly. In the words of botanist Martin Spray, "If some or all of this seems silly, that is partly because we have placed *H. sapiens* at the head of Life's procession".[40] Only with an ethical paradigm shift in favour of all other living creatures will humans step down from this pedestal. As an option, Van Dooren & Rose suggest an *ethics of conviviality* (friendliness), putting the "burden back on humans".[41] To me this would imply being generous towards nonhuman others in planning and transforming our built environment. Technical inventions have enabled humans to perform the work of giants. Our footprints from making our way in landscapes through actions such as tunnel-blasting works, oil drilling and resources extraction are highly visible, and have fundamentally changed landscapes globally, even touching upon the Earth's atmospheric and climate system. Should we not turn our superpowers in the opposite direction, towards reclaiming and cultivating the ecological functions and qualities that are run-down or lost?

A keen communicator arguing nature's case was philosopher Arne Næss (1912–2009). In one of his last books, he suggested *ecosophy* as a comprehensive way of looking at the ecological crisis. Næss had already introduced these ideas in the autumn of 1972, in a lecture given at the 3rd World Future Research Conference in Bucharest. Regarding a multi-voiced *literacy*, Næss argues that ecologists are irreplaceable informants for policymaking and thus change. However, to him ecology is a "*limited* science which make *use* of scientific methods". He questions the belief in science as a value-free zone by proposing a wider perspective: With *ecosophy*, ecology is united with a kind of *sofia – wisdom*[42] containing both norms, rules, value priorities and

40 (Spray, 2019)
41 (Van Dooren & Rose, 2012, p. 19)
42 *Sofia* is the Greek word for wisdom, whilst the prefix eco- refers to the Greek *oikos*, that may translate to household in the sense of being the basis for life on earth.

hypotheses on the state of affairs in the broader universe: "Wisdom is policy wisdom, prescription, not only scientific description and prediction".[43] Næss suggests that such *ecological teams*, composed of scientists from varied disciplines, students and policymakers, would act as caretakers of this worldview. These ecophilosophical practitioners would supposedly act wisely with respect to life on Earth – beyond a strict reliance on scientific facts or truths.

In 1984, Næss and Georg Sessions defined eight principles which express the characteristics of the *deep ecology movement*. Regarding the above reflections, the third principle is of relevance; it states that "Except to satisfy basic needs, mankind does not have the right to reduce this diversity and this richness". By accepting that nature has intrinsic value the last principle points to a responsibility "for trying to contribute directly or indirectly to the realization of the necessary changes".[44] Stating that the deep ecology movement consist of as many "ecosophies as there are supporters"[45], they emphasise the importance of including a variety of views and voices. Actions as a companion to nature must grow from a value base that is adapted to individual capacity – but these together will form a multitude of responsible acts. By this, an ethical foundation for being with nonhuman others will be expressed.

It remains to be seen if we ever can escape from the human standpoint. This debate is seemingly on a gradient from human centeredness to a willingness to see and include nonhuman interests. Næss contributed to positioning nature as "a mentor, measure, and a partner rather than servant".[46] His approach corresponds to Carson's *ethic of wonder* and Van Dooren & Rose' *ethics of friendliness*. All see nature as a partner rather than a provider of useful services. Nevertheless, over the last decade, the concept of *nature services* has become widely accepted within urban planning and management. As an example, the Economics of Ecosystems and Biodiversity (TEEB) was initiated in 2007, as a global initiative focused on drawing attention to the economic benefits of biodiversity and ecosystems as well as the costs of biodiversity loss and ecosystem degradation. From this outlook, urban nature is promoted as being helpful and beneficial to humans. For example, a mature tree has many affordances: Within its root, interactions with soil enhancing microorganisms goes on, and additionally, the roots behave as a natural erosion control. Its trunk and canopy houses song birds and pollinating insects. The foliage gives shade, and trees may have a spiritual standing. As posted by the Norwegian Institute for Nature Research, "The concept of Ecosystem Services provides us with a new tool to communicate the value of nature, putting nature into a perspective based on human needs".[47] Biodiversity is made visible because to ignore it is inefficient, or because there is even the danger that the natural capital might be ruined. From my professional experience, I acknowledge *ecosystem services* as an argumentation-tool which has paved the way for a willingness to invest in *nature-based solutions*. Yet, services are the work of servants. Is it not time to move beyond this perception of nature?

43 (Næss, 1972, p. 99)
44 (Næss, 2002, pp. 108–109)
45 (Næss, 2002, p. 101)
46 (Glasser, 2002, p. xxvi)
47 (Norwegian Institute for Nature Research, 2019)

Tidalscape Actions

The Fjord has several important nature values[48], and as we have seen, marine plants and organisms play important roles in adding to this. To answer the question of whether we have the *responsibility* to return the disturbed seafloor and urban shoreline to a habitable place for all, it is productive to view nature as a mentor and a partner.

A longing amongst people for new courses is seemingly rising. Yet, longing for new directions is not enough. Change requires action. Arne Næss present a good personal example of this as he was an environmental activist and was the first chairperson of Greenpeace Norway when it was founded in 1988.[49] Both Carson and Næss stand out as guides leading us towards a knowledge-based dissemination where compassion for the environment emerges from close identification with, and feeling for, all life forms. Carson's marine fieldwork observations lay the basis for her emphatic and vivid wildlife accounts. Similarly, in Næss' lecture from 1972, the importance of engaging in close encounters with the environment is highlighted: "The ecological field-worker acquires a deep-seated respect, or even veneration, for ways and forms of life. […] To the ecological field-worker, *the equal right to live and blossom* is an intuitively clear and obvious value axiom".[50] A statement reinforced by Næss being an advanced mountaineer, exposing himself to a high degree of interaction with landscapes. Climbing, in a sense, happens as a teamwork between the senses, the vertical rocky walls and gravitational forces – requiring great awareness. Thus, the climber literary participates in a two-way communication with nature.

In my own participation with the marine landscape, my research is spurred by an urge to possibly influence people's mindset as well as the physical appearance of the urban foreshore. Stepping out of my comfort zone and indulging in *wonder as a state of mind*, snorkelling allowed me to be within this fluid world; discovering hitherto unfamiliar shapes, colours and ways of being. Further, by placing various building materials in the sea, I have been able to study how sea wrack develop from tiny spores, to more complex sea plants. I have seen minuscule crabs, barnacles and shells as small as sand grains grow and develop. Thus, I have cultivated a deeper understanding of the blue realm through multisensory observations – which have fundamentally changed my perception and fostered a desire to care for marine environments and creatures.

To achieve acceptance for *nature as an equal partner* and to change the urban development-culture, requires persuasive campaigners. But, before becoming a trustworthy advocate, one must start with becoming aware of and receptive to the often-overlooked wonders and rhythms of the natural world. What kind of neighbourhood and landscape do they need? Through my explorative action research, I have been able to examine these aspects in cross-disciplinary engagements. The first one concerned recommendations for the establishment of new marine landscapes in Bærum,

48 (Chen et al., 2019)
49 (Greenpeace Norway, 2009)
50 (Næss, 1972, pp. 95–96)

a municipality neighbouring Oslo. The second discussed possible restoration actions to strengthen the biological diversity of Oslo's urban sea areas and the Fjord City.[51] The third realized an *undisciplined* co-creation between marine biologist Eli Rinde and myself, through several workshops at a local porcelain factory. In this work we upscaled industrial wreckage products to new marine housing.

Multispecies Housing

Through the aforementioned co-creation-processes, we have articulated a common language for restoring the urban tidalscape, such as a *diversity-enhancing reparation of developed shoreline* and a *diversity-enhancing marine landscape architecture*.
The current extent of using smooth surfaces, straight walls and floor, providing few opportunities for plants and animals to settle, is striking. Additionally, it is highly likely that the light levels reaching the floor will be too low for any algae to grow and thrive. This is illustrated in the figure below, where the co-workers stand on the artificial concrete seafloor of a new building complex in the Fjord City.
As a landscape architect pursuing a *diversity-enhancing marine landscape architecture*, I fall short due to a lack of knowledge regarding all the user groups. In the case of submerged structures, they would be marine plants and animals together with the

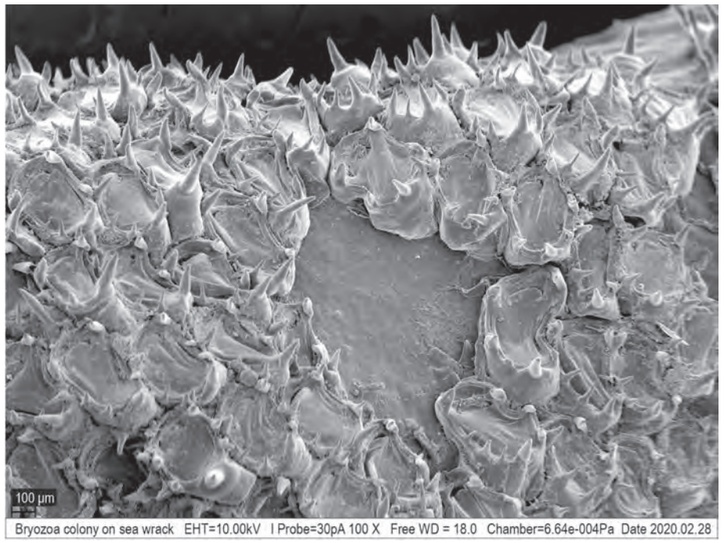


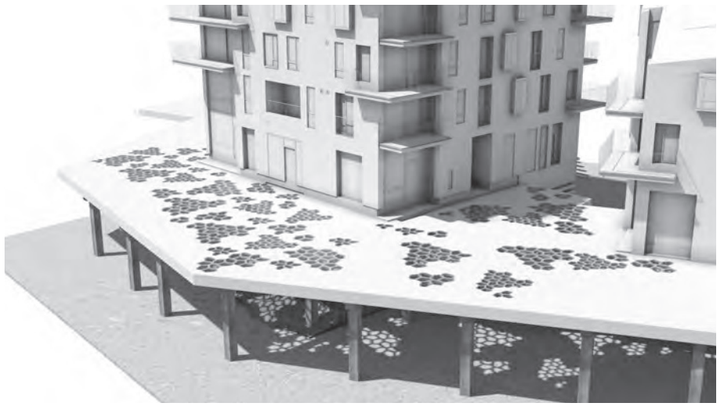
The team of marine biologists, the property developer, and the landscape architect at the building-site of the new urban quarter in Bispevika Oslo. Photo by Elin T. Sørensen © BONO 2018

51 (Rinde, Sørensen & Haraldsen 2019; Rinde et al., 2019)

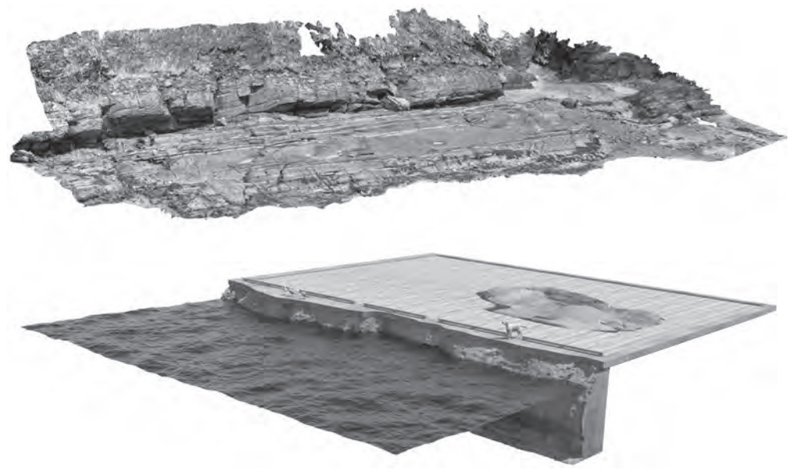
tidalscape features. Here we find a boundless diversity, from small sheltered niches to open spaces exposed to wind and waves. These are qualities and ecological functions spanning from micrometres to kilometres in scale. Marine organisms need folds, cracks and crevices to establish their communities. They opt for irregular surfaces and complex structures. In a review of worldwide ecological engineering measures applied to urban infrastructure, the researchers found that species responding most positively were those whose "body size most closely matched the dimensions of the resulting intervention".[52] Why not create such miniature worlds for marine life onto our built environment? Here the natural rocky shore can teach us a lot about spatial wellbeing factors that are important both to humans and marine organisms. For new designs between land and sea the natural rocky shore is our best mentor and that is why I see the landscape as the true architect.[53]
Humans and marine organisms are non-comparable, yet we share some common needs. Daylight is a key issue within architecture, and light is similarly essential to most marine life. Hence, we all need the benefits arising from forming good neighbourhoods and community living. Also, we have different needs through our life cycle. Along the natural rocky shore, each sea creature seems to have its own specialized way to withstand natural forces, such as seeking appropriate shelters for warding off predators from above and below, and in finding places that keep the creature moist and protect it from drying out, and in breathing within air pockets found in the cracks and crevices of the rocky shore. Hence, the natural shoreline provides creatures with a spatial layout and functionality with similarities to human shelters. Moreover, plants and some animals act as habitat forming species, creating and modifying their own environment. In my imagination, the layered world of kelp forests and seagrass communities resemble productive *residential neighbourhoods*. In the marine world, you find hosts facilitating a great diversity of inhabitants. Here, the plants' stems and leaves, as well as the blue mussel colonies, form three dimensional structures: An "Architecture" influencing currents, creating shelters and functioning as the local food supplier. In this sense, these habitat-forming species afford an undersea lifetime home standard with shelters, nurseries, and a graveyard kept clean by bottom dwelling scavengers. As living-complexes they comprise an interplay between form, function and diversity. Thus, I see them functioning as an all-in-one system from which to draw constructive inspiration.
The creation of a *diversity-enhancing marine landscape architecture* builds upon digital fabrication. For example, photogrammetry is the technique of taking multiple overlapping photographs and from them creating 3D models of objects or scenes. The 3D-models enable large-scale manufacturing, such as large-scale additive manufacturing of three-dimensional objects by means of, for example, extruded cement-based mortar. In this case, close-range photogrammetry is used to record local geological features, and thus enable the transfer of physical features of the natural rocky shore. An example of structural adaption are artefacts with features based upon local geotopes and marine nature types such as *rock pools*. Textural examples may be the

52 (Firth et al., 2016, p. 225; Strain et al., 2018, p. 426)
53 (Rinde & Sørensen, 2019)





Above: In the wild, the individual Bryozoans are minuscule. They join in colonies on rocks, seaweeds and on other sea creatures. Within each colony they live in numerous tiny houses, made from self-produced calcium carbonate. The individual Bryozoan's dwellings are only a few millimetres high, yet they can spread out in metropolises of a whole metre. In the colony they have different tasks. The chefs cook, the doctors are responsible for the children's health and upbringing. They even have their own army guarding the colony. Like mussels and other filter feeders, bryozoans gradually cleanse the water as they feed. Scanning electron microscope (SEM) image shot at the Imaging Centre NMBU, by Lene Cecilie Hermansen & Elin T. Sørensen © BONO 2020
Below: An example of diversity-enhancing marine landscape architecture for the Bispevika quarter, with a light-penetrating surface inspired by Bryozoa-colonies. The model also has a habitat-enhancement landscape element on the artificial seafloor, however this is not visible in this rendering. Concept Elin T. Sørensen, marine guidance Eli Rinde, and 3D-visualisation by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020



Above: A photogrammetry model with 1911 of 1930 aligned images of a Cambric-Silurian tidalscape at Hovedøya, an isle off the Inner Oslofjord. Photogrammetry by Ivar Kjellmo, assisted by Elin T. Sørensen. Kjellmo/Sørensen © BONO 2020
Below: Diversity-enhancing marine landscape architecture in the form of a Cambro-Silurian waterfront. Concept Elin T. Sørensen. 3D-visualisation by Ivar Kjellmo. Kjellmo/Sørensen © BONO 2020

transfer of geological surfaces from the local Cambric-Silurian coastal formations, as shown in the 3D-renderings below. The marine landscape-architectural elements are inspired by marine nature types which are fitting for the conditions of the Inner Oslofjord. Hence, the refined 3D-models suggest new ways of connecting the gap between the urban foreshore and the marine environment.

Another viable option for designing good marine neighbourhoods is to re-create and restore mussel beds, as has been done along the Swedish coast. Filter-feeders like the mussels may help us to clean the waters much in the same manner as certain plants work to remediate contaminated soil. In plant-based remediation processes, the plants are removed after a while and treated as hazardous waste. For the blue mussels, this would imply sacrificing some generations for the sake of better water quality. A more nature-friendly solution would be to let mussels assist in monitoring water quality, keeping us informed on a real-time basis. Inspired by the artist Natalie Jeremijenko, one could imagine that mussel-monitoring units, for instance in the form of sound art pieces, were set up along the urban foreshore – an intervention that would bring life below water to the surface and contribute to public education and awareness raising. Yet another option is to seek inspiration from the blue mussels' time-tested functionalities, such as, for example, the research on byssus threads. In my imagination, I picture building structures that attach to the shore with comparable strength and flexibility as byssus threads, giving us a marine landscape architecture which yields and adapts to the waves and the forces of nature.

One could imagine coastal defence structures put together like mussel beds as a permeable quilt of mussel-patches and empty spaces, retaining and slowing down the wave energy. And what if all plastic ropes used in the sea were replaced by marine-friendly manufactured byssus-like threads. One could just imagine the benefits of a bio-based product which could replace the eight million tons of plastic ending up in the World Ocean (equivalent to ten full grocery bags for every half meter of coastline in the world).[54]

To conclude, Van Dooren & Rose's consideration of the city as a place for a variety of housing potentials, shelters, and habitats that complement each other is uplifting. As they point out: "Humans do not live in burrows or tree tops; there is room for everyone".[55] We have the option to adjust and rethink our built environment, both on land and undersea. Our artificial structures can be made complementary in ways to which *only imagination sets the limits*.

Acknowledgments
I wish to express my gratitude for encouragement and expert advice in developing my doctoral work and this essay – thank you Kristin Bergaust (Oslo Metropolitan University), Ursula Münster (Oslo School of Environmental Humanities), Eli Rinde (NIVA), Ulla Lind (Konstfack – University College of Arts, Crafts and Design), Venke Aure (OsloMet), Anne Beate Hovind, Christian Blom (Norwegian Centre for Technology, Art and Music) and Anne Katrine Geelmuyden (NMBU).

Author's Biography
Elin T. Sørensen is a visual artist, animator and landscape architect, trained in Norway, Finland and Estonia. She is currently a PhD-fellow at the Faculty of Landscape and Society of the Norwegian University of Life Sciences, NMBU. Her practice builds on site-specific concerns and a fascination for nature – especially our relationship to the Ocean. Thus, environmental issues are at the forefront of long-term process-oriented works, often expressed as temporary situations where artefacts return to the original context or material cycle when the show is over. Her research interests include the urban blue, urban ecology and water-management, co-creation practices and more-than-human care. She is currently finalizing a doctoral study with the working title *Making Space for the Urban Blue*.

Correspondence contact information:
elin.sorensen@nmbu.no

Editor's Note
The formatting of this article has been left different from other texts in the book to comply with the author's dissertation.

References
Margaret Atwood (2012). *Margaret Atwood: Rachel Carson's Silent Spring, 50 years on*. Retrieved January 10, 2019, from https://www.theguardian.com/books/2012/dec/07/why-rachel-carson-is-a-saint
Mikhail Bakhtin (1963/1984). *Problems of Dostoevsky's Poetics.* University of Minnesota Press.
Mikhail Bakhtin (1982). *The dialogic imagination: four essays*. University of Texas Press Slavic Series, no. 1. Austin and London: University of Texas Press.
Mikhail Bakhtin (1986). *Speech Genres and Other Late Essays*. University of Texas Press Slavic Series no. 8: University of Texas Press.
Laura Brentner (2002). *Byssal Threads*. Retrieved March 10, 2019, from https://www2.clarku.edu/departments/biology/biol201/2002/lbrentner/byssal_threads.htm
Rachel Carson (1937). Undersea. *Atlantic Monthly, 78* (September), 322–325.
Wenting Chen (NIVA), David N. Barton (NINA), Kristin Magnussen (Menon), Ståle Navrud (Menon), Kristine Grimsrud (SSB), Per Arild Garnåsjordet (SSB), Erik Engelien (SSB), Anne Olga Syverhuset (NINA), Trine Bekkby (NIVA), Eli Rinde (NIVA) (2019). *Verdier i Oslofjorden: Økonomiske verdier tilknyttet økosystemtjenester fra fjorden og strandsonen*. Norsk institutt for vannforskning NIVA-rapport 7420.

54 (Le Guern, 2019)
55 (Van Dooren & Rose, 2012, p. 18)

Hartvig Christie, Stein Fredriksen, Patrik Kraufvelin & Kjell Magnus Norderhaug (2005). Tang, tareskog og ålegras som leveområde og økosystem. In Svenning & Jonsson (Eds), *Kystøkologi: Økosystemprosesser og menneskelig aktivitet. NINAs strategiske instituttprogrammer 2001–2005. NINA Temahefte 31* (pp. 9–17). Norwegian Institute for Nature Research (NINA).
Cineflix (Cities) Inc. in association with THIRTEEN Productions. (2018). *Sinking Cities.* New York, Tokyo, London, Miami, Paris: Cineflix Rights.
Sandra Díaz, Josef Settele, Eduardo S. Brondizio, H. Ngo, Maximilien Guèze, J. Agard, A. Arneth, P. Balvanera, Kate A. Brauman, Stuart Butchart (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES secretariat, Bonn, Germany. Retrieved September 1, 2019, from https://www.ipbes.net/global-assessment-report-biodiversity-ecosystem-services
Encyclopædia Britannica. (2019). Ecosystem. In *Encyclopædia Britannica* (Vol. 2019). Retrieved April 14, 2019, from https://www.britannica.com/science/ecosystem
Louise B. Firth, Antony M. Knights, Danielle Bridger, Ally J. Evans, Nova Mieszkowska, Pippa J. Moore, Nessa E. O'Connor, Emma V. Sheehan, Richard C. Thompson & Stephen J. Hawkins (2016). Ocean sprawl: challenges and opportunities for biodiversity management in a changing world. In R. N. Hughes, D. J. Hughes, I. P. Smith, & A. C. Dale (Eds.), *Oceanography and Marine Biology: An Annual Review* (1st ed., Vol. 54). CRC Press, Taylor & Francis Group.
Jorge Fitz-Gibbon (2019, September 5). Hurricane Dorian causes $7B in property damage to Bahamas. *New York Post*. Retrieved October 1, 2019, from https://nypost.com/2019/09/05/hurricane-dorian-causes-7b-in-property-damage-to-bahamas
Harold Glasser (2002). Introduction. In A. Naess, *Life's philosophy: Reason & feeling in a deeper world* (pp. xiii–xxxi). Athens & London: University of Georgia Press.
Philippe Goulletquer (2004). Cultured Aquatic Species Information Programme. Mytilus edulis (Linnaeus, 1758). In *FAO Fisheries and Aquaculture Department*. Retrieved April 13, 2019, from http://www.fao.org/fishery/culturedspecies/Mytilus_edulis/en
Greenpeace Norway (2009). *Takk til økofilosofen Arne Næss*. Retrieved April 5, 2019, from https://www.greenpeace.org/archive-norway/no/press/releases/takk-til-okofilosofen-arne-naes/
Dehlia Hannah (2017). Natalie Jeremijenko's New Experimentalism: Dehlia Hannah in Conversation with Natalie Jeremijenko. In Richard Grusin (Ed.), *Anthropocene Feminism*, (p. 256). USA: University of Minnesota Press.
Havforskningsinstituttet (2019). *Tema: Blåskjell*. In Tore Strohmeier & Øivind Strand (Eds). Retrieved April 1, 2019, from https://www.hi.no/hi/temasider/arter/blaskjell
Stefanie Hessler (2018). Tidalectics: Imagining an Oceanic Worldview through Art and Science. In S. Hessler (Ed.), *Tidalectics – Imagining an Oceanic Worldview through Art and Science* (pp. 31–80). Cambridge, Massachusetts: The MIT Press Massachusetts Institute of Technology, co-published with London: TBA21-Academy.
Alex Horton & Jasper Ward (2019, September 6). A father put his son on a roof to protect him from Dorian's surge. The 5-year-old was swept away. *The Washington Post*. Retrieved October 1, 2019, from https://www.washingtonpost.com/world/2019/09/06/father-put-his-son-roof-protect-him-dorians-surge-year-old-was-swept-away
Martin Irvine (2004). *Bakhtin: Main Theories*. Retrieved from http://faculty.georgetown.edu/irvinem/theory/Bakhtin-MainTheory.html
Claire Le Guern (2019). When the Mermaids Cry: The Great Plastic Tide. *The Santa Aguila Foundation and Coastal Care.org*. Retrieved September 20, 2019, from http://plastic-pollution.org/
Susanne Liljenström (2019, August 21). Forskarna vill säkra musslornas framtid. *Extrakt* [Online Newspaper]. Retrieved from https://www.extrakt.se/forskarna-vill-sakra-musslornas-framtid/?fbclid=IwAR2ON4rEuKPzZW9ftNcTw058jVhulTTN4N3JDxV96M_EWKDjkyh3pIfe7Z4
Max Planck Society (2017, March 2). Mussel byssus threads produced by a combination of self-assembly processes and biologically active steps. *Science X (Phys.org)*. Retrieved April 13, 2019, from https://phys.org/news/2017-03-mussel-byssus-threads-combination-self-assembly.html
Robin McKie (2012, May 27). Rachel Carson and the legacy of Silent Spring. *The Guardian*. Retrieved March 15, 2019, from https://www.theguardian.com/science/2012/may/27/rachel-carson-silent-spring-anniversary
Miljødirektoratet (2016, June 2). Definisjon: SMVF (Sterkt modifiserte vannforekomster). *Miljødirektoratet [Norwegian Environment Agency]*. Retrieved September 5, 2018, from https://www.vannportalen.no/tema-a-a11/1a-fysiske-endringer/2a/definisjon-smvf/
Stein Mortensen (2018, July 6). Forskerne svarer: Hvorfor forsvinner blåskjellene? *Havforskningsinstituttet (The Institute of Marine Research)*. Retrieved July 25, 2019, from https://www.imr.no/hi/nyheter/2018/juli/forskerne-svarer-hvorfor-forsvinner-blaskjellene
Norwegian Institute for Nature Research (2019). *Ecosystem Services*. Retrieved January 7, 2019, from https://www.nina.no/english/Ecosystem-Services
Johan Petter Nystuen (personal communication, 2017–2020). *Professional dialogues between Professor Emeritus in geology Johan Petter Nystuen and landscape architect Elin T. Sørensen, during the period of Sørensen's doctoral study*.

Arne Næss (1972). The Shallow and the Deep, Long-Range. Ecology Movement. A Summary. *Inquiry: An Interdisciplinary Journal of Philosophy, 16*(1–4), 95–100.
Arne Næss (2002). *Life's philosophy: Reason & feeling in a deeper world*. Athens & London: University of Georgia Press.
Oslo Havn (2011). *Maritim kulturminneplan for Oslo havn.* Oslo Havn KF 2011.
Mary Louise Pratt (1991). Arts of the Contact Zone. *Profession 91*, Modern Language Association: 33-40.
Eli Rinde & Elin T. Sørensen (2019, September 19). Mind the Gap – the Blue Common. Uncovering and Improving the Urban Blue [Abstract]. *Common Ground. International Federation of Landscape Architects IFLA – World Congress 2019,* Oslo, Norway, September 18–20, 2019. The Book of Abstracts. Oslo: International Federation of Landscape Architects / NLA, p. 137.
Eli Rinde, Elin T. Sørensen & Trond Haraldsen (2019). *Anbefalinger tilknyttet planer for etablering av nye landskap ved Lakseberget og Telenor-stranda på Fornebu. En uttalelse fra et tverrfaglig fagforum opprettet av Bærum kommune* [Statement and Recommendations on Plans for Establishing New Landscapes at Lakseberget and Telenor Beach at Fornebu]. Oslo: NIBIO, NIVA & NMBU.
Eli Rinde, Elin T. Sørensen, Mats G. Walday, Camilla With Fagerli, Hartvig Christie, André Staalstrøm, Line Johanne Barkved, Henry Simmons, Harald Bonaventura Borchgrevink (2019). *Reetablering av biologisk mangfold i Oslos urbane sjøområder*. [Restoration of Biological Diversity of Oslo's Urban Sea Areas]. Oslo: NIVA & NMBU NIVA report 7426-2019.
Eli Rinde (personal communication, 2016–2020). *Professional dialogues between marine biologist Eli Rinde and landscape architect Elin T. Sørensen, during the period of Sørensen's doctoral study.*
Anthony A. Robson, Carlos Garcia De Leaniz, Rory P. Wilson, Lewis G. Halsey (2010). Behavioural adaptations of mussels to varying levels of food availability and predation risk. *Journal of Molluscan Studies, 76*(4), 348–353. https://doi.org/10.1093/mollus/eyq025
Christopher Small & Robert J. Nicholls 2003. A global analysis of human settlement in coastal zones. *Journal of Coastal Research* 19, 584–599.
Martin Spray (2019). Third division. *ECOS, 40* (1). Retrieved April 11, 2019, from https://www.ecos.org.uk/ecos-401-third-division/
Jennifer Stitt (2019, September 27). For Rachel Carson, wonder was a radical state of mind, edited by S. Dresser. *Aeon Online Newspaper*. Retrieved September 20, 2019, from https://aeon.co/ideas/for-rachel-carson-wonder-was-a-radical-state-of-mind
Elisabeth M. A. Strain, Celia Olabarria, Mariana Mayer-Pinto, Vivian Cumbo, Rebecca L. Morris, Ana B. Bugnot, Katherine A. Dafforn, Eliza Heery, Louise B. Firth, Paul R. Brooks, Melanie J. Bishop (2018). Eco-engineering urban infrastructure for marine and coastal biodiversity: Which interventions have the greatest ecological benefit? *Journal of Applied Ecology, 55*(1), 426–441. https://doi.org/10.1111/1365-2664.12961
Elin T. Sørensen (2018). On urban hard surfaces. In Anne Elisabeth Toft & Magnus Rönn (Eds). *The Production of Knowledge in Architecture by PhD Research in the Nordic Countries*, NAAR Proceedings Series, Vol. 1, pp. 411–441. Sweden: Nordic Academic Press of Architectural Research.
Thom van Dooren & Deborah Bird Rose (2012). Storied-places in a multispecies city. *Humanimalia: a journal of human/animal interface studies, 3*(2), Spring 2012, 1–27.
Francesca von Habsburg (2018). A Renaissance for the Oceans. In S. Hessler (Ed.), *Tidalectics – Imagining an Oceanic Worldview through Art and Science* (pp. 7–8). Cambridge, Massachusetts: The MIT Press Massachusetts Institute of Technology, co-published with London: TBA21-Academy.
World Commission on Environment and Development (1987). *Our common future*. Oxford: Oxford University Press.
Craig Zagata, Christy Young, Joanne Sountis & Melanie Kuehl (2008). Mytilus edulis. *Animal Diversity Web*. Museum of Zoology, University of Michigan. Retrieved April 13, 2019, from https://animaldiversity.org/accounts/Mytilus_edulis/
Leikny Øgrim & Monica Johannesen (2014). *Action Research*. Retrieved March 13, 2019, from https://film.oslomet.no/action-research

Enhancing marine biodiversity along urban shorelines: stepwise guidelines for an urban blue habitat framework, a marine neighbourhood toolkit and a common learning platform

Short title: How to enhance marine life and human well-being in urban sea areas

Authors: Elin Tanding Sørensen[1] and Eli Rinde[2]

Affiliations:

1: School of Landscape Architecture, Faculty of Landscape and Society Norwegian University of Life Sciences (NMBU), Norway.

2: Section for Marine Biology, Norwegian Institute for Water Research (NIVA), Oslo, Norway.

Abstract

As urbanisation and climate change are accelerating the loss of marine species and habitats worldwide, there is a pressing need to identify strategies and adaptive solutions to reverse this trend. To safeguard and rebuild marine life in urban sea areas require a common understanding of the constraints human impact imposes on marine organisms. We need to identify, design and test solutions that can be implemented in an adaptive long-term perspective, however such strategies demand establishing a common language and learning platform between the different disciplines and professions involved.

By working together for several years with redevelopment sites by the inner Oslofjord in Norway, the two authors — a marine biologist and a landscape architect — have started articulating a common language to identify and define appropriate nature-based solutions for creating healthy marine neighbourhoods. Our experiences embrace cross-disciplinary cooperation between geologists, oceanographers, social scientists, urban planners, developers, architects and municipal caseworkers, and yields step-by-step guidelines for the entire building process, general principles for marine-life friendly design and a toolkit for marine nature-based solutions. The guidelines and the toolkit are centred around identifying limitations and to find solutions to the main constraints for marine life and humans' connectedness to marine nature in urban sea areas. From our observations, much can be mitigated through new ways of building into the sea.

To succeed in promoting marine life in "urban deserts", there is an overall need to explore and test nature-based solutions in an adaptive manner, hence we promote the creation of living blue labs as common, cross-disciplinary learning platforms. Such collaboration provides a golden opportunity to co-develop marine neighbourhoods that meet the needs of marine life and human beings. Over time, living blue labs can potentially evolve into a solid basis for a holistic adaptive management of the urban blue commons and become important arenas for a much-needed ocean literacy. In this context, urban redevelopments offer a great potential to realise living-labs.

Keywords: urban coastal developments, marine nature-based solutions, marine neighbourhoods, diversity-enhancing reparation of developed shoreline, marine nature and well-being

Background and learning cases

We are rapidly losing species and ecosystem functions worldwide and there is an urgent need to rebuild marine biodiversity (1). Due to increased urbanization and climate change, the coastal seascapes are under threat and vulnerable for additional pressures (2-4). To safeguard and rebuild marine landscapes and its associated ecosystem in urban shorelines, we need a common understanding of the threats and the limitations human impact imposes on the coastal environment. It is imperative to identify solutions to reduce, mitigate or reverse the negative impact of human-built environments.

Coastal urbanisation and the associated coastal hardening (5-7) influence the living conditions for marine species in several ways, like available habitats and living environmental conditions. However, artificial structures in the sea can be modified to better marine habitats, as demonstrated in several papers by Strain, Evans, Firth and colleagues (4, 8-10). For instance, Dafforn and colleagues presented a conceptual ecological framework for designing artificial structures with multiple functions, including improved provision of ecosystem functions and less adverse ecological impacts (11). Still we lack an overall framework, a structured manual and an appropriate toolkit on planning and implementing nature-based solutions in urban landscapes. Moreover, through our cross-disciplinary learning process in the inner Oslofjord, we have i) noticed a large knowledge gap about marine life and a lack of awareness on the marine environment in an urban context and ii) experienced that the marine research community and the urban development sector in Norway act within two separate worlds. To safeguard the life below water, there is a need to join forces and to co-create solutions. Through practical work and the gathering of knowledge from literature, we have identified some essential limiting factors for marine life in the urban shores. From our observations, much can be mitigated through new ways of building into the sea. These experiences have paved the way to develop an overall framework that we call the *urban blue habitat framework*, comprising a step-by-step manual of the process as well as an assemblage of nature-based enhancement tools and methods in a *marine neighbourhood toolkit*.

"Nature-based solutions are actions that are supported and inspired by or copied from nature, to protect, manage and restore natural or modified ecosystems, which address societal challenges, effectively and adaptively, providing human well-being and biodiversity benefits." (12, 13).

Nature-based solutions and eco-engineering

By increasing the resilience of society to environmental stressors and contributing positively to human health and well-being, nature-based solutions are seen to offer more opportunities than the conventional urban grey infrastructures, in particular in the marine environment (2). Nature-based solutions aim to help societies to address a variety of environmental, social and economic challenges in sustainable ways. Hence, the creation of marine nature-based designs for the purpose of restoring or rebuilding marine life in urban sea areas, demand a broad approach: it must be founded on the combination of research, innovation actions and cooperation between stakeholders, disciplines, and the marine environment itself. To simultaneously promote marine life, human well-being, climate change adaptation and mitigation, crossing professional borders and including manifold interests is a prerequisite.

There is a long tradition in using ecological principles as the basis of infrastructure designs that enhances the structures ecological value, also known as eco-engineering (14). However, combining engineered structures and dynamic natural ecosystems features, such as coastal wetlands, can result in 'hybrid' solutions that perform better than the engineered solution alone (15). Restoration or protection of coastal wetlands and marine habitats, such as blue forests in urban areas, will expand the ecological functioning of areas, e.g. damping of waves, reducing erosion risks to the engineered structures, carbon storage, promoting fisheries production, and biodiversity conservation (16). Although the transferability and upscaling of marine nature-based solutions need further research and a broader scope (16), we urge stakeholders to engage in evidence-based practices that develop viable *in situ* nature-based solutions which is the core of the concept *urban living laboratories* (12).

Before presenting the urban blue habitat framework, with its stepwise approach, we give an overview of seven practical learning cases that all except one is located within Oslo's urban area. As these initiatives have afforded meeting points between diverse actors, we see the cases as preliminary living laboratories, of which the learning outcome is shared in this paper.

The site as laboratory – the practical learning cases

Between 2018-2020, as a cross-disciplinary team, we have been promoting the use of urban development processes as living test-sites for marine-life friendly improvements. These initiatives address the re-naturing of artificial shorelines and marine landscape reparation at sites along Oslo's waterfront.

Our focus has been to raise awareness about urban developments that promote thriving environments for both marine life and humans. To communicate this inclusive perspective, we have named this approach "*to facilitate for multifunctional marine neighbourhoods*." Communication with a broad set of stakeholders and fellow scientists together with public outreach events have been a vital part of the learning process. The timeline of the different learning cases and our main tasks, the associated outreach activities, our co-creators, and the lessons learned are summarized in Figure 1.

The Fjord City is described as Norway's most ambitious waterfront renewal project: it is the biggest urban development in Norwegian history and is even seen as one of Europe's largest waterfront transformations, offering a nine kilometre stretch of sites in transition from industrial harbour to new residential and recreation areas. The fjord is mainly presented as a scenery for the new homes and outdoor life, and not as a dynamic body of water and a living environment. Looking at the developer's residential adverts, the sea is depicted as an opaque surface only reflecting the clouds in the sky. There are no signs of marine life or the three-dimensional landscape undersea. A similar lack of marine recognition is reflected in the waterfront's architecture, with limited choices for the marine settlements. Except for large-scale removal of polluted sediments in Oslo's inner harbour between 2006-2011 (17), and the deployment of small-scale measures such as artificial reefs and blue mussel ropes at the three sites Tjuvholmen, the Oslo Opera House and Sørenga (18), there is not yet a long-term plan to protect, repair or rebuild marine life in Oslo's urban sea areas. These efforts altogether have improved the living conditions for humans and has demonstrated the ability for the area to house marine life.

Figure 1 on the next two pages, gives an overview of the learning cases, including the timeline, tasks, outreach activities, co-creators and learning outcomes that form the basis for this paper.

Case 1: An eelgrass growth trial in Lohavn

Case 1 involved transplantation of habitat-forming eelgrass (Zostera marina) from a nearby meadow as a small-scale biodiversity enhancement experiment at Lohavn, and it was uncertain whether the marine plant could thrive within a sheltered industrial port remain in Oslo's urban intertidal. The opportunity to get engaged in this site was due to the developer's interest in temporary events as a part of the ongoing redevelopment process.

The growth trial was carried out as an ad-hoc experiment, hence not integrated in the master planning of the area. Our interest was to grow eelgrass in wood-pallets corresponding to the urban farming on land. The boxes were intended to be suspended from the remaining concrete dock, at three levels in order to study if and at which depth level the plants could thrive, in the dark, murky urban sea water. As eelgrass is considered as a vulnerable marine habitat type, the transplantation of eelgrass from a local population, triggered the need to apply for a permit from the County Governor.

The trial was contextually related to the site close location to the art project "Flatbread Society/Losæter." Today, Losæter has grown into a new cultural institution, dedicated to a range of activities related to art and urban food production (19). In this regard, besides experimenting with the growth of eelgrass, we sought conveying the ethnobotanical aspects: such as the practical uses of this plant according to traditional knowledge of different cultures.

The trial period lasted from February to August 2018, as a co-creation between the authors, urban developer Anne Beate Hovind, developers from Bjørvika Infrastructure (BI), the marine biologist Hartvig C. Christie (NIVA), and divers from the diving association Project Baseline Oslo. During the short planning phase, also a timber technologist was involved.

Although the eelgrass-experiment in Lohavn was not implemented due to the developer's cancellation, we got valuable practical experiences with respect to material choice, timing of the process, and the how to do the trial in practice. One major issue was deploying untreated wood boxes into the sea because of marine wood-boring species (20).

2018

2019

2020

2021 and forward

avoid degradation of exsisting intact nature

precautionary principle

March–ongoing

Marine landscaping and land reclamation from use of local rock materials in Lysakerfjorden, Bærum municipality
Task: advisory board, planning for repair and recreation of coastal landscapes by reusing local rock material.
Report: "Statement and recommendations on plans for establishing new landscapes at Lakseberget and Telenor-beach at Fornebu."
Co-creators: municipal caseworkers, landscape architect & marine biologist, soil specialist.

March

Marine landscaping and land reclamation from use of local rock materials
Communication: follow-up meeting.
Co-creators: municipality caseworkers, marine biologist & landscape architect, soil specialist.

multispecies team

facilitation cascades

Frebruary–August

Lohavn transformation site
Task: planning for an eelgrass growth trial.
Co-creators: urban planner, landscape architect & marine biologists, developer, timber technologist, Viken county council.

October–December

Oslo's urban sea areas
Report: "Restoration of biological diversity of Oslo's urban sea areas."
Co-creators: marine biologists, oceanographer, social scientist & landscape architect, municipal caseworkers.

January

Oslo's urban sea areas
Communication: a follow-up meeting and a public meeting.

May–ongoing

Filipstad new urban residential area
Task: part of an ad-hoc knowledge-group on behalf of Oslo Waterfront Planning Office.
Co-creators: marine biologist, municipality caseworkers.

need for testing and monitoring

safe and circular materials

timing

June

Bispevika new urban residential area
Task: planning for an eelgrass bed and other marine enhancement solutions.
Co-creators: urban planner, landscape architect & marine biologists, developer.

April

June

Outreach: "Mulighetsrommet i fjæra" (The Urban Intertidal as Opportunity Space), discussing a marine knowledge center for urban soltions in The Fjord City Oslo with diverse co-creators.

April

Bispevika new urban residential area
Task: contributing with a marine landscaping statement for the preliminary conference at The Agency for Planning and Building Services, City of Oslo.
Co-creators: landscape architect, architects, developer.

urban blue-lab potential

holistic long-term perspective landscape connectivity

site-sensitive design

public outreach

ocean literacy

September

Outreach: IFLA – World Congress "Common Ground", Oslo. Oral presentation: "Mind the Gap – the Blue Common."
Co-creators: urban planner, landscape architect & marine biologist, head of Oslo Waterfront Planning Office.

January

Outreach: International Temperate Reef Symposium, Hong Kong. Poster: "Urban Underwater Landscape and Tidal Gardens – is it Possible to Transform Seafloor Deserts in Oslo Harbour to Underwater Oasis?"
Co-actors: landscape architect & marine biologists, urban planner, developer.

November

Outreach: participatory meeting commissioned by Port of Oslo, led by Rodeo architects.
Oral presentation: "Mind the Gap – the Blue Common"
Co-creators: marine biologist & landscape architect.

March–ongoing

Grønlikaia new urban residential area
Task: part of a knowledge-group on behalf of Port of Oslo, led by Rodeo architects.
Co-creators: landscape architect & marine biologist in a cross-disciplinary group.

Figure 1. An overview of the learning cases, including the timeline, tasks, outreach activities, co-creators and learning outcomes that form the basis for this paper. Lessons learned and the main principles achieved from these practical efforts are emphasized in the colored circles. Diagram by Eli Rinde & Elin T. Sørensen © BONO 2020.

We also experienced limited time for enough preparation of the trial, including obtaining the needed allowances and for anchoring the project to the project owner. Carrying out a complex experiment based on voluntary efforts, and outside the ordinary planning process, contributed to high uncertainty in the planning process. All in all, the time-limit for this case was too short to result in a viable solution. Timing, allocation of resources, and a robust interaction platform emerged as some of the factors needed to succeed in this trial.

Case 2: Marine gardens in new residential quartiers in Bispevika

Case 2 included an ad-hoc experiment on establishing a seagrass bed on the artificial concrete building foundation of the quartier that was already in the construction phase. Together with Anne Beate Hovind, we voluntarily engaged in developing a demo-case for facilitating marine life within the submerged parts of a new residential quartier in Bispevika. This gave an opportunity to start a cross-disciplinary dialogue and development of design drafts for a variety of coastal eco-engineering measures. To keep the building pit dry, seawater was held back by means of a Larssen steel-sheet-piling retaining wall: a situation providing optimal conditions for retrofitting marine landscaping solutions to the concrete landscape before the seawater was released into the construction. The inflow of seawater was scheduled for late in summer in 2019. For this site, we developed marine soft- and hard-bottom gardens for the submerged hardscape's floor and walls. The recommended soft- and hard garden designs and modifications of the loadbearing pillars, were inspired by the international community of eco-engineering practitioners (4, 5, 9, 21).

One important aspect of the nature-based design was to use local Cambro-Silurian surplus rock material generated from regional infrastructure projects, as a basis for the miniature marine landscape. This material choice encouraged further research into the reuse of local rock material, including consideration of how the structures should be developed or modified to improve light conditions and water quality. This can be done by creating openings in the dock and 'lifting' the seafloor to allow seagrasses to grow. Other options are to maximise the exchange of water and creating a variety of micro-habitats with different hydrodynamics. It is also critical to create a design that allow for monitoring and statistical analysis of the effect of the different measures, like how marine life respond to different textures and sizes. Moreover, we pinpointed the importance of accessibility to the marine gardens in order to perform the needed maintenance required for good ecological status. In this context, removing invasions of alien species is one essential caretaker task. To perform this maintenance, we suggested a team of "marine gardeners."

Relatively far into the design process we learned that the concrete deck could hold the load of the residential construction only, implying that no extra weight on the concrete seafloor was possible. We were also informed that the loadbearing pillars' rebar demanded a certain thickness of concrete coating for protection. This implies that the proposed retrofitting for creating marine settlement surfaces by means of drilled crevices and holes of different sizes and placement would impact the robustness of the pillars. Finally, and quite unexpectedly, it was decided to remove the steel-sheet-piling and release seawater into the building-site in the spring instead of summer, which made the marine re-landscaping impossible to realise. After the stranded demo-case, we were invited to follow up a possible implementation of marine neighbourhoods adapted for the masterplan for the new residential projects in the adjacent area. According to the project timeline, the design for these quartiers must be completed by the end of 2020.

The initial phase went from June 2018 to April 2019. This learning case involved meetings with urban planners, the project developer and contractor, researchers from the natural sciences, like marine biologists, oceanographers, social scientists and the contracted landscape architect of the residential quartier responsible for the landscaping on land. The process resulted in several outreach activities. Some of the ideas was presented as a poster at an international conference in Hong Kong January 2019 (22). We also gave an invited presentation for the International Federation of Landscape Architects IFLA – World Congress "Common Ground," September 2019 (23).

The lack of success in implementing the suggestions was due to a mismatch between the project progress and the ad-hoc experiments. Our contacts within the project management were not informed of the overall timeline, and the initiative was introduced too late to be integrated in the completion of the housing quarter. A key lesson learnt is that coastal eco-engineering interventions need to be a part of the planning from the start.

Hence, the master plan must account for scaling of dimensions such as volume and weight, material choices, and maintenance responsibilities. Again, timing is crucial together with a robust framework for such complex experiments involving living material.

Case 3 and 4: Landscape scale transformation of the shoreline in Bærum

Case 3 included establishment of an artificial island for recreational purpose, and case 4 included enlargement of an earlier uniform shoreline-landfill for the European route E18 in Sandvika, bordered by a small craft marina. During the search for local surplus rock material from regional infrastructure projects for the suggested re-landscaping in case 2, we were in contact with Bærum municipality and their need to reuse huge quantities of rock from tunnel projects. The contact resulted in the formation of a cross-disciplinary advisory board as part of the municipality's process of re-using the material for landscape scale transformation of their shoreline, to which the two authors were invited to participate. The municipality aimed for a sustainable re-use of the surplus rock material, including the potential to initiate measures that could enhance the marine life in the area.

The board unanimously agreed that the planned artificial island would result in a large, irreversible intervention within a unique Cambro-Silurian geotope possessing important biological, geological and landscape values (24). As the site appear intact and house large biodiversity values on different spatial scales as well as aspects, there is no need for biodiversity-*enhancing* actions in the area. However, for the existing uniform road fill in Sandvika, the board approved the plans and recommended to repair the landscape to an organic shoreline formation that that mimics the natural variations of the rocky shore (24). March 2020, Bærum municipality arranged a cross-disciplinary follow-up meeting to prepare for alternative designs for the artificial island. The aim was to discuss how to reduce the adverse impact regarding the mentioned landscape qualities of this location. Hence, the process is ongoing, both with concern to adapt to the board's recommendations of safeguarding the intact shoreline together with the marine-life friendly reparation of the uniform shoreline-landfill along E18.

One essential lesson from case 3 & 4 was in regard to the precautionary principle highlighted by the Nature Diversity Act (25), which we experienced as not being used actively. The plans for the recreational island was presented as a nature-improving measure, however, as explained above, with some unfortunate effects: The enormous quantities of rock material produced from major infrastructure projects are a societal matter. Hence, the proposal for building the artificial island was motivated for cost-effective reasons. The municipality's initiative to establish a cross-disciplinary board to advice the plans is exemplary. By this, critical weaknesses of the plans were revealed, not least the risk of erasing irreplaceable local nature values. Followingly, the board suggested marine friendly ways to handle the surplus rock material. One urgent matter addressed is the benefits of coordination across administrative boundaries in relation to long-term sustainable urban development processes.

Case 5: Rewilding *The Fjord City*

Case 5 aimed to identify areas and possible measures for enhancement of marine life. October 2019, the authors together with a team of researchers from NIVA, won a competition announced by the Agency of Urban Environment to perform a feasibility study on the rewilding of Oslo's urban sea areas and the Fjord City waterfront. The work involved a field survey as well as a collective 'rewilding' brainstorm with participation from marine researchers at NIVA within the fields of marine biology, oceanography, social sciences, caseworkers from the Agency of Urban Environment and the Waterfront Planning Office together with landscape architects from NMBU. In this process we identified four important components that most of the limiting factors for marine life could be related to. These were human disturbances such as discharges and activities in the sea, the lack of suitable terrain and growth surfaces, and unsuitable environmental conditions. These components also form the core basis for the framework and the toolkit presented below. More precisely it addresses how to improve the terrain, growth surfaces and the environmental conditions, if needed, to enhance and stimulate the presence of native species. Because of the general validity of these factors, this approach is probably relevant for different urban environments, worldwide.

To make it easier for the municipality to select solutions relevant to different levels of ambitions or funding, we suggested solutions on three different spatial scales: small, medium and large-scale interventions.

We advised for an overall and long-term planning and implementing of the suggested nature-based solutions, that allow to observe, learn and adjust in accordance to the responses from marine life. To establish a landscape ecological connectivity, we suggested to create vital undersea stepping-stones for marine life. This is inspired from the pollinator passage on land, that from its launce in 2015 has expanded throughout the city of Oslo, creating flowering stepping-stones where pollinators find food and shelter all over the city (26). An overarching aim was to pave the way for marine communities by means of establishing facilitation cascades: that may "occur when a habitat-forming species facilitates another habitat-forming species with synergistic effects on biodiversity." (27). At landscape scale, we proposed repairing the uniform fillings and the artificial hardscapes by means of creating an organic shoreline formation that that mimics the variation of the natural rocky shore. At small scale, we launched the idea of creating marine neighbourhoods like the conventional thinking of terrestrial neighbourhoods, offering diverse eco-engineering interventions. The study was published in a December 2019 (18), and presented at a Directors meeting at the Agency of Urban Environment, and in a public meeting hosted by Oslo Waterfront Planning Office in January 2020.

Working with the rewild-report, in addition to the above-mentioned learning cases, have formed the foundation of articulating a common language for creation of multifunctional marine neighbourhoods. The 'rewild-study' summarises key-concepts for marine nature-based solutions, such as: *a diversity enhancing landscape architecture* that build on designs that mimics the natural shoreline's variation in horizontal and vertical design, as well as its geological diversity. *Diversity-promoting and three-dimensional marine habitats* denotes small-scale solutions such as establishing *hanging marine gardens*, *blue forests* and communities of *filtering animals*. As a rule of thumb, we suggest that the new interventions should be guided by the spatial, biological and geological qualities of local rocky- and soft-bottom shore formations and local marine nature types. Figure 3 shows how the marine nature type maerl has inspired surface complexity and colours on submerged walls, pillars and artificial seafloors.

The way forward in a young field

The timeline for the development of the remaining transformation areas in *The Fjord City* vary between a few and up to 30 years. Accordingly, the above efforts represent a first preparatory stage in urban transformation. Given the many limitations and unknown factors within the young field of marine nature-based solutions, the most appropriate and pre-cautionary ways of managing biodiversity and ecosystem functioning is minimizing interventions and working with nature whenever possible (4, 9). To achieve this in urban development, ideally the preparation, planning, implementation and adaptation of solutions should develop as *urban living blue-labs*. The implementation of marine nature-based solutions in the urban context must be introduced at the very start of the master planning processes. Trough stakeholder involvement from the start of the project, and through error and trial of different approaches, this will allow for the most 'optimal' site-specific solutions. The precise effect of eco-engineering interventions are difficult to predict because ecosystems are highly variable with many uncontrollable factors (10), hence it is important to foster site-specific approaches that match the target taxa and the dominant stressors within an area, as well as to apply a range of approaches that can enhance different groups of organisms, to maximise diversity (4).

We suggest stepwise guidelines for the different phases of the development, to promote healthy *marine neighbourhoods* as the goal of the interventions, embracing good living conditions for both people and marine life. The *marine neighbourhood toolkit* provides some general design principles to facilitate diverse and vigorous marine communities along urban waterfronts. The delineated step-by-step guidelines in the *urban blue habitat framework* can be used as a manual for accomplishing nature-based solutions in blue urban development. Our hope and motivation are that the framework and the tools may be helpful in improving the communication between the broad set of stakeholders within urban developments, both in Norway and in other countries.

The Urban Blue Habitat Framework

These step-by-step guidelines are founded on a three-phased process divided into five steps, as visualised in Figure 2 on the next two pages. Step 1-2 addresses *preparation and site assessment*, step 3-4 *planning and implementation* and finally, step 5 focus on *adaptation*.

Step 1: Gathering site-specific knowledge

Our experience from the learning cases above show the importance of site-specific knowledge of the environment both on small and large spatial scale. This includes biological, geological, oceanographical and other site-specific environmental information. To be able to build for healthy marine neighbourhoods in the developed sites, all projects involving coastal eco-engineering solutions, should be based on knowledge of the area's native species, their habitat requirements and the status of the general environmental conditions. If such knowledge is missing, pre-studies should be undertaken to gather all needed site-specific knowledge. Environmental factors that are of particulate importance for marine life are:

1. Local geology; which influence substrate types as well as other terrain features that affect species distributions; the presence of rock and sediments, slope and terrain ruggedness.
2. Oceanographic parameters, e.g. currents and waves, temperature, salinity, oxygen levelsand.
3. Marine values within an area, e.g. the presence of key or threatened species and nature types, geological assets, the general distribution of species within the area, and the areas value for recreation.

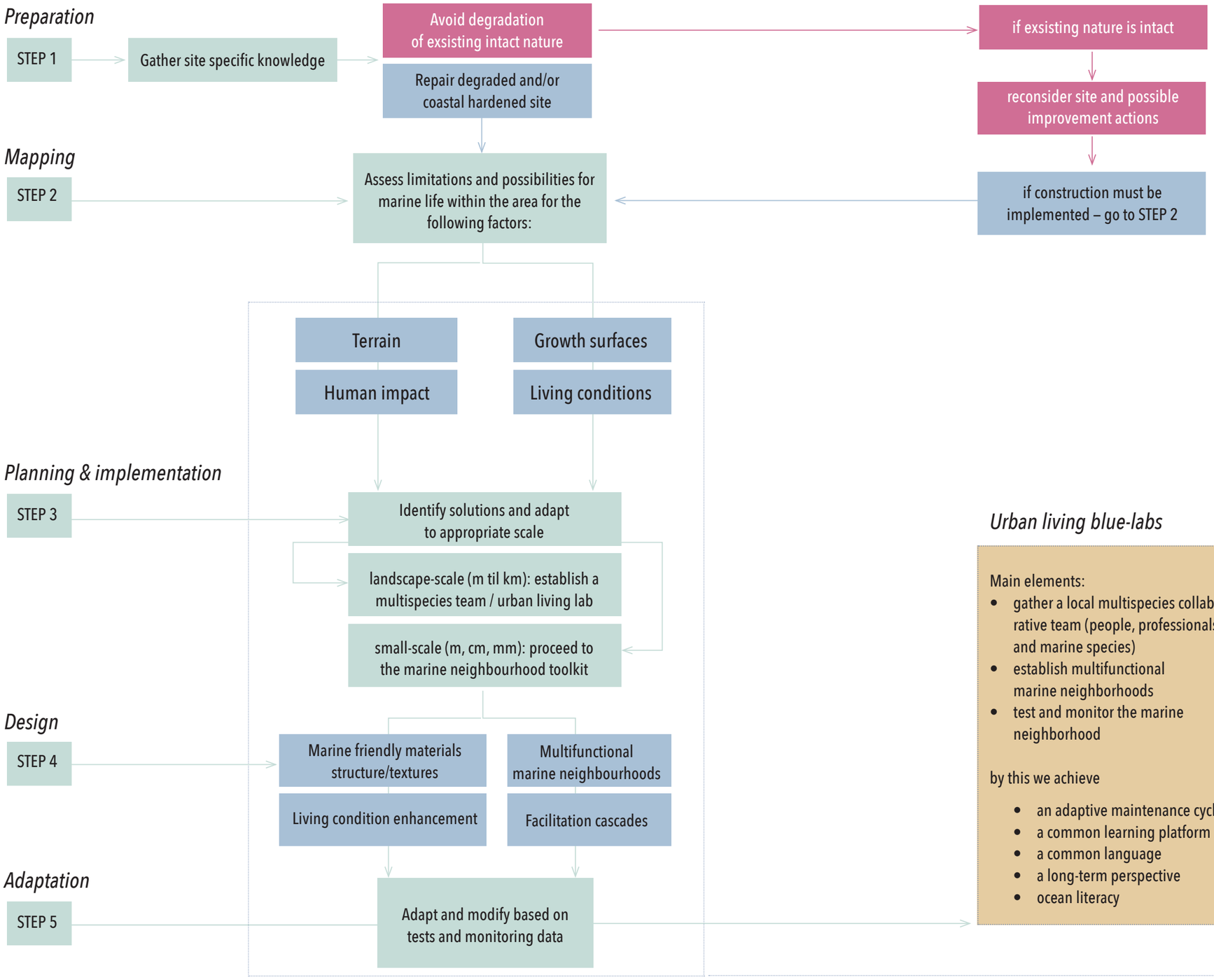
A new study shows that the recreational values of the Oslofjord in general is very high (28). The study was based on Statistic Norway's living condition survey, that every third year include questions on recreation. Hence the ecological state of the fjord has an impact on many of the region's citizens. In general, there is a strong link between ocean and human health encouraging development of healthy marine communities (29-31).

One critical principle for safeguarding biological diversity is to avoid degradation of existing intact nature. To be able to act according to this principle, the mentioned gathering of site-specific knowledge is a prerequisite. Case 3 with the planned artificial island, showed, however, that knowledge of intact and valuable nature systems does not necessarily give enough leverage to avoid landscape alterations along shorelines. As a general principle, cooperation across regional scale should form the basis of sustainable strategies concerning the disposal of local rock material. Such a practice would have allowed for investigation of alternative locations for the material, including the opportunity to use local surplus rock to repair human-altered seascapes in the Oslo region (24).

Step 2: Identifying possibilities and limitations

Step 2 involves assessing the site's possibilities and limitations for marine life based on the knowledge gathered in step 1. We recommend that this assessment is focused on the four essential factors identified for marine life in the 'rewild study': human disturbances, terrain and growth surfaces, general environmental living conditions, and how interventions can be used to accomplish the opportunities and to counteract the limitations. Human disturbances and potential negative impacts must be identified and resolved if possible. One critical issue is how to achieve integrated urban water management. For instance, heavy discharges of particles and sewage into the sea in periods with heavy rainfall is a major problem in many urban areas. Several nature-based solutions exist to reduce this problem and to improve water quality (cf. *The marine neighbourhood toolkit* for examples). Within urban Ports, the seafloor is often excavated to make space for large cargo traffic. Landscapes that are too deep or too steep makes it hard for the growth of habitat forming seagrasses or macroalgae. The creation of shallower and more gently sloping terrain, with the right substrate conditions, provide thriving environments for such species. A wide range of options exist to modify growth surfaces to allow for more species rich communities (10): of which some examples are shown in Figure 3 and 4.

The urban blue habitat framework



Urban living blue-labs

Main elements:

- gather a local multispecies collaborative team (people, professionals and marine species)
- establish multifunctional marine neighborhoods
- test and monitor the marine neighborhood

by this we achieve

- an adaptive maintenance cycle
- a common learning platform
- a common language
- a long-term perspective
- ocean literacy

The marine neighbourhood toolkit

Terrain and growth surfaces:

- diversity-enhancing landscapes (m, km)
- nature-like shoreline formation (m, km)
- three-dimensional marine habitats (mm, cm, m)
    - hanging marine gardens
    - filtering animals
    - blue forests

Human impact and marine living conditions, mitigations and improvements:

- light condition
    - light entrance
    - "lift" the seafloor
- water exchange
    - large- and/or small-scale water exchange measures
    - water exchange friendly architecture
- urban water management
    - riverine and coastal vegetation buffer zones
    - other nature-based solutions
- climate- and weather-proof design
    - marine nature-based solutions
    - amphibious landscapes and architecture

Adaptive management cycle:

- blue stewardship
- sensors and other monitoring masures

Figure 2. A step-by-step approach for planning and designing marine nature-based solutions adapted for urban waterfront renewals and its process stages. Diagram by Eli Rinde & Elin T. Sørensen © BONO 2020.

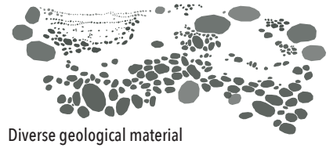
Marine neighbourhood toolkit

from limiting factors such as uniform and fragmented landscapes and habitats

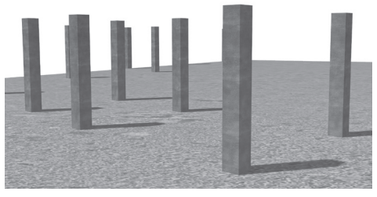
... to diverse and connected three-dimensional marine landscapes and habitats



Uniform seafront edge



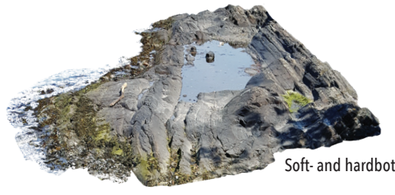
Diverse geological material



Uniform pillars and seafloor



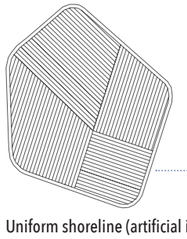
Diversified pillars and seafloor



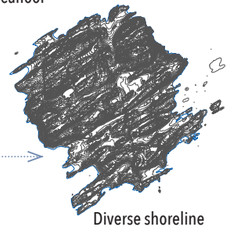
Soft- and hardbottom gardens



Uniform surface



Uniform shoreline (artificial island)



Diverse shoreline



Diverse textured surface

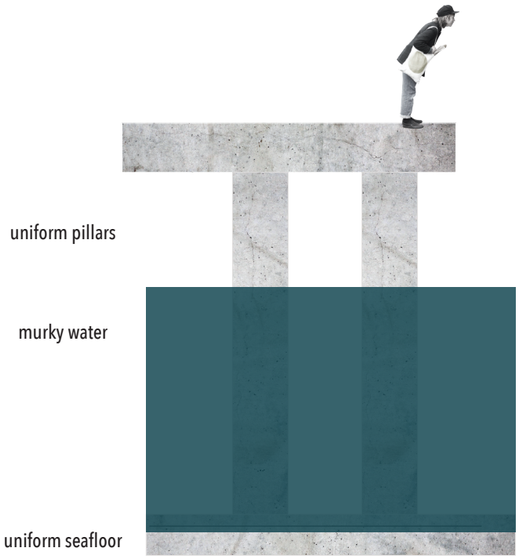
Terrain and growth surfaces

Terrain features
(landscape-scale)

- depth
- slope
- overhang
- edges

Growth surfaces
(small-scale)

- access
- type
- grain size
- complexity



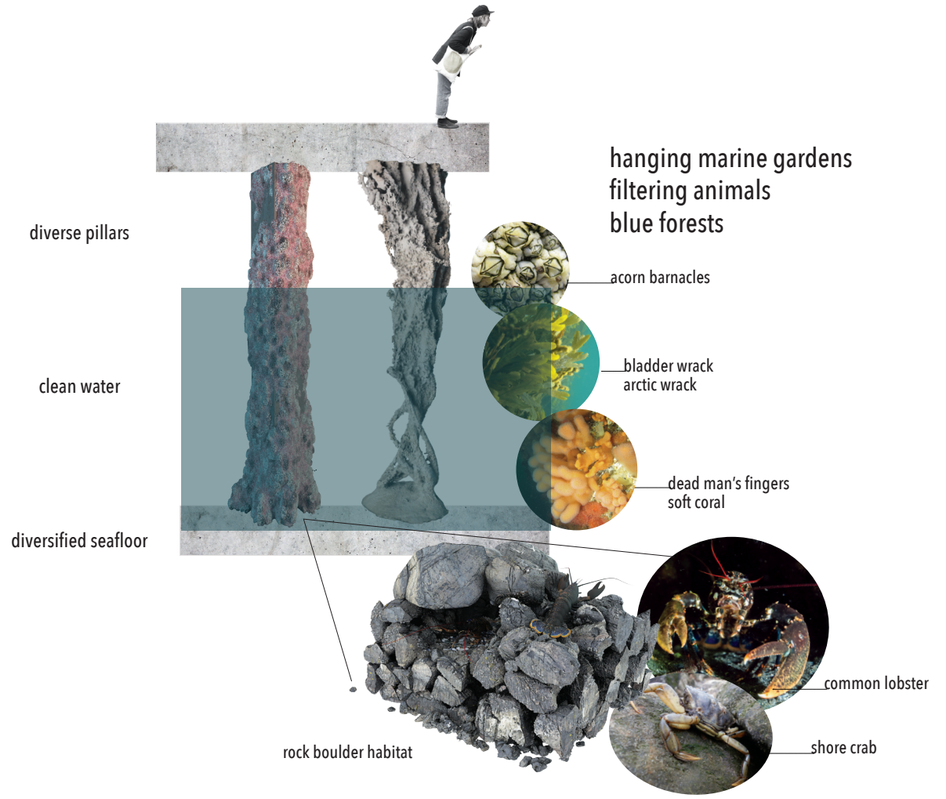
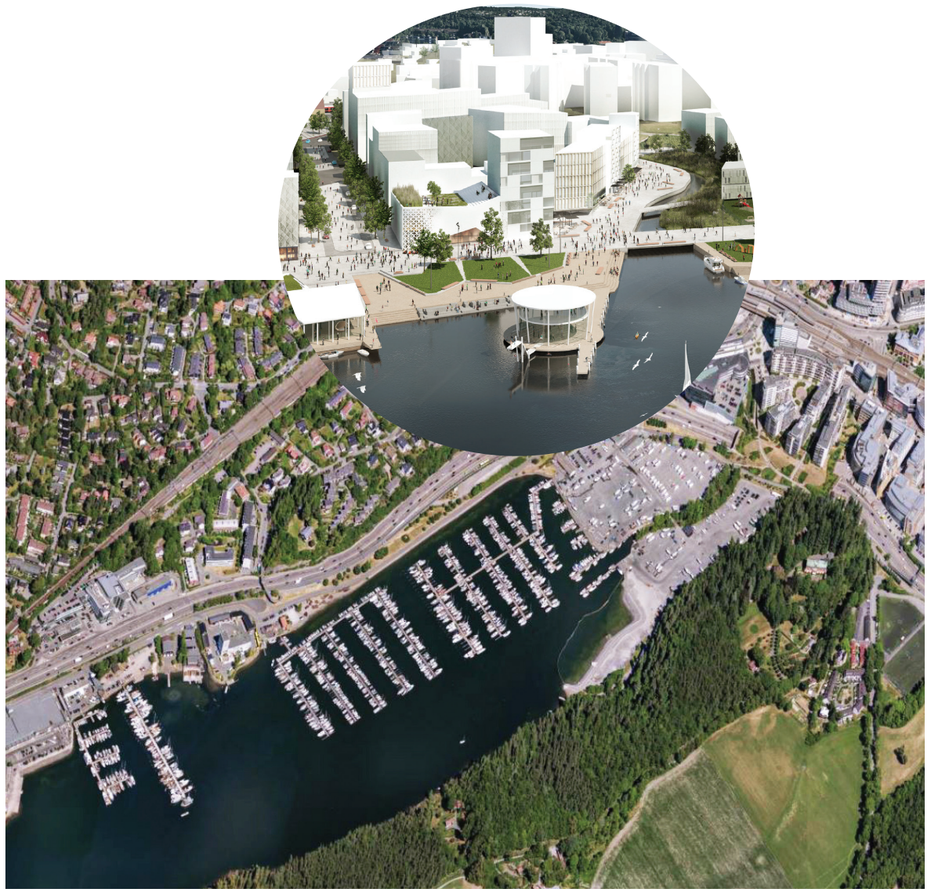


Figure 3 and 4 on the next pages. The marine neighbourhood toolkit: limitation and possible solutions to improve novel terrain and growth surfaces to support marine life, and to mitigate or reduce the negative effects of human impact to enhance marine living conditions. Diagram by Eli Rinde (NIVA) and Elin T. Sørensen (NMBU). Underwater photos by NIVA. 3-D visualisation by Ivar Kjellmo.
BONO © 2020.

Marine neighbourhood toolkit

from limiting factors



Human impact and marine living conditions

Human impact

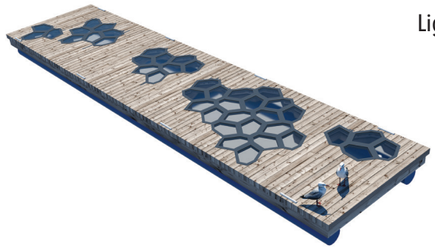
- development actions
- boat traffic
- fishing
- marine littering
- erosion
- sedimentation and re-suspension of particles
- nutrient loading
- pollution
- alien species

Living conditions

- low light
- high turbidity
- smothering of plants and animals
- habitat loss
- oxygen deficiency
- redused water exchange
- high nutrient loading
- global warming
- weather and climate extremes

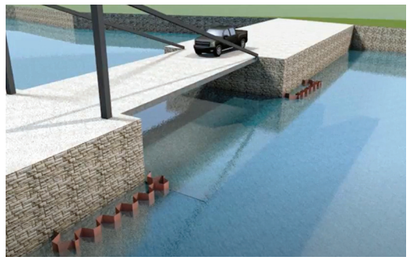
Above: possible design of the seafront at Sjølyst, from the report "Bestumkilens miljøtilstand og virkninger av områderegulering Skøyen" published by The Agency for Planning and Building Services, City of Oslo 2019, p. 18 (fig. 21). Diagram by Eli Rinde (NIVA) and Elin T. Sørensen (NMBU). 3-D visualisation by Ivar Kjellmo. Visualisation of tidal port by Ivar Trondsen.
Photo of coastal buffer zone by Elin T. Sørensen © BONO 2020.

... to blue livable solutions



Light condition improvement

- light entrances
- "lift" the seafloor



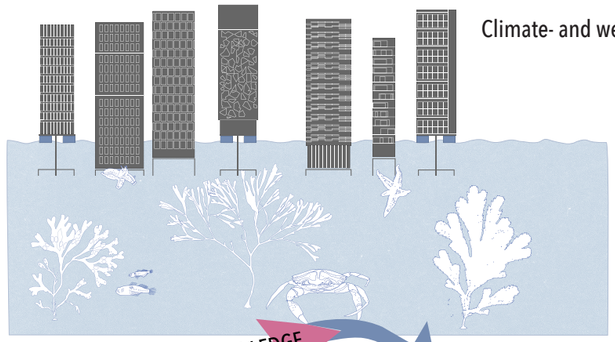
Water exchange measures

- large- and/or small-scale
- water exchange friendly architecture (e.g. tidal port)



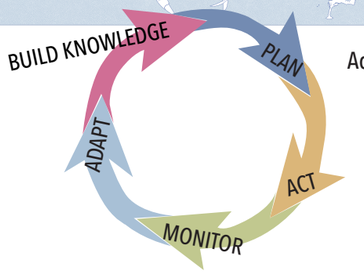
Integrated urban water management

- riverine and coastal vegetation as buffer zones and natural erosion control
- green walls and biotope roofs, rain beds, permeable covers etc.



Climate- and weather-proof design

- marine nature-based solutions
- amphibious landscapes and architecture



Adaptive management cycle:

- blue stewardship
- sensors and other monitoring masures

Artificial structures such as marinas and floating docks may hamper the living conditions for several species through reduced light and rate of water exchange (18). Including light entrances into the structures is a way to resolve this (Figure 4). To improve water circulation one possibility is to reduce the size of the marina or restructuring the floating elements. Also recommended is to design floating pontoons with diversity-enhancing habitat features in marine-life friendly materials.

The traditional replacement of natural diversity by uniform designs such as smooth and steep concrete structures in urban areas, hamper a thriving milieu for algae and marine animals (8, 9). In contrast, we recommend learning from observations of intact biotopes in adjacent areas when developing new designs. *The neighbourhood toolkit* (Figure 2) provides guidelines towards solutions that mimic the natural shoreline as well as the natural three-dimensional habitats formed by algae and animals. For further inspiration, an overview of identified limitations and possibilities for marine life in the 'rewild' study is shown in Supporting information, Tables 1-2.

Step 3: Identify solutions at appropriate temporal and spatial scale

The first step in planning and implementation is to identify solutions to mitigate the recognised limitations and to strengthen the living conditions within the designated marine neighbourhood. Eco-engineering methods concerning textures and structure enhancements — whether retrofitting onto existing structures or designed as integrated parts of the architecture — often happen on small, location scale: defined as a millimetre to meter level. Reparation of human-altered shorelines or large-scale modification of the seascape, happen on a landscape scale, from meter to km. Furthermore, the timescale of the development process can allow for both short-term and long-term interventions. Hence the appropriate solutions need to be identified at the right temporal and spatial scale.

For boosting marine life in urban areas, four co-operating strategies are proposed. The first is to use marine-life friendly materials, structures and textures. There is a critical need to avoid deploying plastic in the ocean, as the debris is disintegrated into microplastic. Likewise, materials that may leak harmful toxins into the environment should also not be used. The second strategy is improving the living conditions degraded by human-built environments. To this aim, nature-based solutions should be prioritized, such as establishing soft edges and vegetation buffers along bodies of water as part of integrated urban water management. The third is to establish multifunctional marine neighbourhoods that ensure self-sustaining healthy ecosystems. Indeed, good examples are the diverse communities designed by habitat forming species such as seagrasses, kelps and mussels that provide nursery and feeding areas for other species, and hence form important links within the marine neighbourhood.

Moreover, several studies emphasise the significance of offering a locally adapted diversity of microhabitats in artificial structures in order to create viable marine communities (5, 9, 21). Such methods embrace suitable habitats for all life stages of the native inhabitants in the neighbourhood. Lastly, the fourth strategy address stimulating the creation of facilitation cascades (27, 32), for example through co-restoration of kelp, seagrasses and mussel reefs. This is a rather new, yet promising approach worth pursuing, especially in urban areas were the environmental conditions often are deteriorated, and several coordinated actions are needed to enhance marine biodiversity. The above-mentioned habitat forming species, all has the additional benefit of cleaning the water: kelp and seagrass use nutrients for growth, and the mussels filter particles from the water in a very efficient manner, both functions that improve the water quality for a range of other species. The eco-engineering efforts should consider the possibility to give rise to landscape ecological connectivity at a large spatial scale. The potential for large-scale facilitation depend on the projects character and timeline. The appropriate spatial scale depends on site-specific conditions, and not least on the developer's ambitions with respect to funding, and the willingness to invest in marine nature-based solutions.

Step 4: Create a multispecies collaborative team

To reach the best possible site-specific solutions, we recommend that the project is directed by a multispecies collaborative team, preferably as long-term explorations within the context of *living blue-labs*. The concept of *a collaborative multispecies team* emphasises critical consideration of both the needs of marine species and humans to design common liveable neighbourhoods.

It is vital to base the implementation of upscaled long-term solutions on testing and monitoring the failure and success of short-term and small-scale solutions. Renewals of heavy altered seascapes on a landscape scale must be performed from a holistic perspective, considering the combined impact of all interventions within the area. The potential to create and stimulate facilitation cascades (27) should be evaluated. One critical finding from the 'rewild study' is that the implemented small-scale enhancement measures in *The Fjord City* was carried out without an overall plan concerning neither connectivity nor stewardship and monitoring. For cultivating the benefits from facilitation cascade strategies, existing enhancement measures should be included as part of new rewilding projects. Together they should form the basis of trial and error approaches within an adaptable learning platform.

Step 5: Adapt and modify, designing through learning from natures responses

Due to the lack of practical experiences of marine restoration in urban environments, we recommend implementing an adaptive management that allow for adjustments along the way. Adaptive management implies that novel solutions should be flexible and adjustable, both on a short- and long-term, i.e. by observing and monitoring how marine life and the general living conditions respond to the different eco-engineering methods. A common need for adjustment can be related to wrong choices of materials, structures and textures of the built environment, or promoting the spread of invasive species. Depth is another critical issue, as for example if the landscape is too deep to support photosynthesis of the chosen plants/algae. Failure of succeeding to transplant/promote the chosen habitat foundation species is not unlikely. To support adaptive management, valid statistical designs and monitoring tools and sensors are needed to identify when modifications are required.

Hence, adaptive management demands thorough planning, identification of criteria and thresholds for success and failure of the interventions. Not least the monitoring of biological factors, such as species composition, survival and growth rates, physical parameters like temperature, salinity and oxygen. To set the directions for appropriate adjustments, one must gather as much information as possible on the predicted or actual crossing of given thresholds.

This approach is strongly supported by the guidance from leading researchers within the field of coastal eco-engineering. They urge the practitioners to be caution when reporting on small-scale experimental trials, and in contrast pay larger attention to when experiments 'fail' or yield unintended outcomes. Further, they "*advise revisiting, repeating and expanding on experiments to test responses over broader spatio-temporal scales to improve the evidence base.*"(2) Adaptability and transparency are especially relevant within an unpredictable planning regime that will happen 30 years into the future, both regarding unknowns of human and marine settlements as well as the future impact of climate change.

Urban blue labs as a tool to achieve multispecies co-creation

Nature-based solutions should mimic how non-human communities cope with environmental extremes (33). This approach embraces a multispecies perspective, where we especially consider the interaction between humans and non-human others. The European Commission also underlines that the creation of new resilient urban ecosystems must build on local conditions: as nature-based solutions deliver benefits to diverse stakeholders, such efforts should include a full stakeholder spectrum and their multiple value orientations (12). Such learning platform should ideally be composing of a multispecies collaborative team of local stakeholders, professionals and detailed knowledge gained from observing local marine species interactions. To anchor the blue-labs locally, one option is to involve cooperation between researchers and schools in testing and monitoring.

The concept of "testbeds" is introduced to explore appropriate solutions as part of the development strategy for *Oslo's Harbour Promenade*. This is motivated from operating with an open attitude towards the dynamic character of urban planning, and the fact that public spaces are continuously evolving in responses to impulses from the surroundings. "Testbeds" is thus about introducing different programs along the waterfront according to a step-by-step approach. The intention is to let the introduced solutions grow organically in response with the local community. Along the Harbour Promenade, several temporary test-sites have been utilised, of which some will be implemented on a permanent basis if they prove viable.

So far, these have been carried out on land. The “testbeds” suggested as floating elements on the Fjord are floating gardens and aquaculture systems, sauna, water sports clubs and bathing facilities. Except several small floating saunas, other floating installations are not yet realized (34, 35). In one sense, the testbed concept has a certain likeness to living laboratories with special emphasis on bottom-up initiatives. Inviting the users to participate and hence anchor the activity programs, is seen to meet social and democratic aspects of a sustainable urban development.

The core of suggesting *living blue-labs* for the implementation of nature-based solutions build on the creation of site-specific designs, both ecologically and by means of social and stakeholder inclusion. Site-specific urban experiments should be carried out in a one-to-one scale, through the shifting seasons and yearly development. This gives an opportunity to learn from natural processes and user’s interaction over time. There is great a potential in using urban waterfront renewals as living labs. As a resourceful country, Norway both hold the knowledge and the responsibility to support urban development innovations. As we experience, the project owners with decision mandate now show a strong interest in exploring urban living blue-labs to design marine diversity enhancement solutions and as a basis for an adaptive management and stewardship. As a general principle, the stewardship of the marine ‘gardens’ should be treated equally as the stewardship of the parks and public green spaces’ on land.

The Marine Neighbourhood Toolkit

The creation of *marine neighbourhoods* is a strategy to make people aware of the importance of marine life as an essential part of the urban blue-green infrastructure. The “blue garden” is not yet acknowledged as equal to the parks and public green spaces on land. However, we claim that to establish “blue gardens” as an integrated part of the urbanised shoreline is important to peoples’ health and well-being. Many studies show that the opportunity to be close to nature in urban environments are essential to people’s health and well-being — benefits applying no less to the marine environment (36).

The marine neighbourhood toolkit provides guidelines on how to approach the search for solutions to the four limiting factors, and general advices for an adaptive management cycle. The mentioned factors are universal, but not exhaustive. Hence other sites in other regions can have additional issues that need to be handled and solved. The use of this toolkit demands site-specific knowledge of the natural variation in the biological and a-biotic environment. Figures 3-4 illustrate different marine nature-based solutions to the four, we assume universal limiting factors, based on the experiences from our learning cases. The solutions are inspired by the native species and seascape within inner Oslofjord and show how the fillings and pillars can be modified or designed to create more niches and space for a diverse marine life (Figure 3). Further, examples are given of solutions that can improve light conditions, water exchange and urban water treatment (Figure 4). Some examples from the authors experimentations with using porcelain as a non-toxic material for modifications and new marine houses is given (Figure 5). The importance of developing climate-ready nature-based solutions that can handle future challenges with extreme events such as heat waves, heavy rainfall and flooding, is pinpointed.

Human impact and the ambient *living conditions* are closely linked. From working with the ‘rewild-study’, we found that the main mitigation and improvement actions could be narrowed down to these measures: improvement of light conditions, water exchange, urban water management, and to develop climate- and weather-ready designs. To improve the light conditions, one can create openings in otherwise opaque surfaces such as floating docks. Another viable method is ‘lifting’ the seafloor and hence reclaiming the earlier shallow subtidal and tidal flats in coastal areas. The City of Malmö’s successful establishment of a large seagrass bed in the city centre is an excellent role model concerning the re-use of local rock material and re-naturing urban sea areas (37).

Water exchange measures can be integrated on small and large spatial scale, in temporal testbed, or within a bay or residential area. One example shown in Figure 4, is a tidal port that can be used to force the water in one direction and allow for water exchange rather than a back-and-forth movement of water masses in an enclosed area. By simple means of a water pump, it is possible to improve the water exchange rate and hence the oxygen conditions for large seafloor areas with relatively low costs (18). We advise that urban designs should be constructed with the marine life’s need of well-being factors such as light, water flow and clean water and the designed structures impact on these.

The use of riverine and coastal vegetation in urban water management (cf. Step 3), has a large beneficial potential. Such nature-types can tolerate flooding and at the same time reduce erosion and sedimentation rates, that otherwise will cause darkening of coastal waters. An overview of suggested mitigation actions to ameliorate the limiting factors in our study area, is given in Supporting information, Table 2.



Figure 5. Examples of the authors experimentation with porcelain. Left: Photo from Norwegian Technical Porcelain by Eli Rinde (NIVA). Right: Photos from "HAV" by Joe Urrutia, Annike Flo (NOBA) and Elin T. Sørensen (NMBU). Rinde/Sørensen © BONO 2020.

Concluding reflections

Our engagement and wide stakeholder-communication has resulted in increased awareness of the importance and need to consider marine life when building into the sea. We advocate the concept of *marine neighbourhoods* as tool to strengthen the relation between human beings and the marine environment.

Long-term engagement in the process of urban redevelopments for several sites in the municipalities Bærum and Oslo have laid the foundation for the guidelines in the presented *urban blue habitat framework* and the *marine neighbourhood toolkit*. This framework, the stepwise approach and the suggested tools make us better equipped for the coming tasks in planning and implementation of marine nature-based solutions to be adapted for the remaining transformation sites along Oslo’s waterfront.

The growing interest in marine life form a promising basis for creating *living blue-labs* that allow co-developing, testing and monitoring marine neighbourhoods. This also gives a platform for an adaptive management of urban blue renewals and developments. To succeed, monitoring and identification of threshold values to determine success or failure of the different solutions, is needed. Marine nature-based solutions should be implemented in ways that make it possible to modify and adapt to unforeseen impacts and development of urban coastal ecosystems. We believe that the framework and toolkit presented in this paper can be applied in manifold urban contexts around the world, to the benefit of marine life and human beings.

Acknowledgments

We wish to thank the Faculty of Landscape and Society at Norwegian University of Life Sciences NMBU for the opportunity of Sørensen's Ph.D-fellowship: A landscape architectural research mentored by urban developer Anne Beate Hovind, marine biologist Eli Rinde and geologist Johan Petter nystuen. The development of the thesis digital fabrication and 3-D designs are co-created with 3-D expert Ivar Kjellmo. Thanks to Andreas Treu (NIBIO) for valuable input on timber, and Runa Tunheim (NMBU) for assisting the landscape architectural analysis and visualisations.

Furthermore we wish to show our grattitude to the Agency of Urban Environment, and their caseworkers Harald Magnus Kvifte, Thomas Andrè Ruud and Jan Olav Nybø, and Liv Marit Dønnem Søyseth at the Oslo Waterfront Planning Office, and to Bærum municipality, with caseworkers Ingvild Tandberg, Terje Skryten, Ellef Ruud, and Grethe K. Løvald for giving us the opportunity to undertake two of the studies that forms the basis of this paper: the 'rewild study' concerning The Fjord City, and the landscaping projects in Bærum. We also must thank colleagues at NIVA for their contribution to the 'rewild study' and the field survey: Mats G. Walday, Harald Bonaventura Borchgrevink, and Henry Simmons who was a guest student from Plymouth University. Not least for valuable contributions to the work: Hartvig C. Christie, Camilla With Fagerli, Line Johanne Barkved, and oceanographer André Staalstrøm. In addition, we thank urban developer Karl Jon Sørli at Oslo S Utvikling (OSU) for inviting us into the discussions of diversity enhancing measures in Bispevika, as well as The Port of Oslo and Rodeo Architects for the honour of being chosen as participants in the know-ledge hub for Grønlikaia development site. We also thank Hartvig C. Christie (NIVA) and Norith Eckbo (Sabima) for useful comments.

References

1. Carlos M. Duarte, Susana Agusti, Edward Barbier, Gregory L. Britten, Juan Carlos Castilla, Jean-Pierre Gattuso, Robinson W. Fulweiler, Terry P. Hughes, Nancy Knowlton, Catherine E. Lovelock, Heike K. Lotze, Milica Predragovic, Elvira Poloczanska, Callum Roberts & Boris Worm. Rebuilding marine life. Nature. 2020: 580 (7801): 39-51. DOI: https://doi.org/10.1038/s41586-020-2146-7

2. Louise B. Firth, Laura Airoldi, Fabio Bulleri, Steve Challinor, Su-Yin Chee, Ally J. Evans, Mick E. Hanley, Antony M. Knights, Kathryn O'Shaughnessy, Richard C. Thompson & Stephen J. Hawkins (2020). Greening of grey infrastructure should not be used as a Trojan horse to facilitate coastal development. *Journal of Applied Ecology*: 7. DOI: https://doi.org/10.1111/1365-2664.13683

3. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental. Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany.; 2019. https://ipbes.net/global-assessment

4. Elisabeth M. A. Strain, Celia Olabarria, Mariana Mayer-Pinto, Vivian Cumbo, Rebecca L. Morris, Ana B. Bugnot, Katherine A. Dafforn, Eliza Heery, Louise B. Firth, Paul R. Brooks & Melanie J. Bishop (2018). Eco-engineering urban infrastructure for marine and coastal biodiversity: Which interventions have the greatest ecological benefit? *Journal of Applied Ecology*, 55: 426–441. DOI: https://doi.org/10.1111/1365-2664.12961

5. Melanie J. Bishop, Mariana Mayer-Pinto, Laura Airoldi, Louise B. Firth, Rebecca Morris, Lynette H.L. Loke, Stephen J Hawkins, Larissa A. Naylor, Ross A Coleman, Su Yin Chee & Katherine A Dafforn. Effects of ocean sprawl on ecological connectivity: impacts and solutions. Journal of Experimental Marine Biology and Ecology. 2017;492 (Supplement C) :7-30. DOI: https://doi.org/10.1016/j.jembe.2017.01.021

6. Rachel K Gittman, S. Scyphers, Carter S. Smith, Isabelle P. Neylan & J. Grabowski. Ecological Consequences of Shoreline Hardening: A Meta-Analysis. BioScience. 2016;66:763-73. DOI: https://doi.org/10.1093/biosci/biw091

7. Rachel K. Gittman, Charles H. Peterson, Carolyn A. Currin, F. Joel Fodrie, Michael F. Piehler & John F. Bruno. Living shorelines can enhance the nursery role of threatened estuarine habitats. Ecological Applications. 2016: 26(1): 249-63. DOI: https://doi.org/10.1890/14-0716

8. Ally J. Evans, Louise B. Firth, Stephen J. Hawkins, Alice E. Halle, Joseph E. Ironside, Richard C. Thompson & Pippa J. Moore. From ocean sprawl to blue-green infrastructure:
A UK perspective on an issue of global significance. Environmental Science & Policy. 2018: 91: 60-9. DOI: https://doi.org/10.1016/j.envsci.2018.09.008

9. Louise B. Firth, Antony M. Knights, Danielle Bridger, Ally J. Evans, Nova Mieszkowska, Pippa J. Moore, Nessa E. O'Connor, Emma V. Sheehan, Richard C. Thompson & Stephen J. Hawkins (2016). *Ocean sprawl: challenges and opportunities for biodiversity management in a changing world*, vol. 54. Oceanography and Marine Biology: An Annual Review: Taylor & Francis.

10. Kathryn A. O'Shaughnessy, Stephen J. Hawkins, Ally J. Evans, Mick E. Hanley, Paul Lunt, Richard C. Thompson, Robert A. Francis, Simon P. G. Hoggart, Pippa J. Moore, Gregorio Iglesias, David Simmonds, James Ducker & Louise B. Firth (2020). Design catalogue for eco-engineering of coastal artificial structures: a multifunctional approach for stakeholders and end-users. *Urban Ecosystems* volume 23, pp. 431–443 (2020) https://link.springer.com/article/10.1007/s11252-019-00924-z?shared-article-renderer

11. Katherine A. Dafforn, Tim M. Glasby, Laura Airoldi, Natalie K. Rivero, Mariana Mayer-Pinto & Emma L. Johnston. Marine urbanization: an ecological framework for designing multifunctional artificial structures. Frontiers in Ecology and the Environment. 2015: 13(2) :82-90. DOI: https://doi.org/10.1890/140050

12. European Commission Environment Directorate (2019). *Appendix 1—Marine Habitat types definitions. Update of "Interpretation Manual of European Union Habitats" Natura 2000 in the Marine Environment*: European Commission Environment Directorate. Available at: https://ec.europa.eu/environment/nature/natura2000/marine/docs/appendix_1_habitat.pdf (accessed: June 3, 2020).

13. IUCN. Blue Infrastructure Finance: A new approach, integrating Naturebased Solutions for coastal resilience. 2020: https://www.preventionweb.net/publications/view/71224

14. Scott D. Bergen, Susan M. Bolton & James L. Fridley. Design principles for ecological engineering. Ecological Engineering. 2001;18: 201–10. DOI: https://doi.org/10.1016/S0925-8574(01)00078-7

15. Stijn Temmerman, Patrick Meire, Tjeerd J. Bouma, Peter M. J. Herman, Tom Ysebaert & Huib J. De Vriend. Ecosystem-based coastal defence in the face of global change. Nature. 2013: 504(7478): 79-83. DOI: https://doi.org/10.1038/nature12859

16. Zhenchang Zhu, Vincent Vuik, Paul J. Visser, Tim Soens, Bregje van Wesenbeeck, Johan van de Koppel, Sebastiaan N. Jonkman, Stijn Temmerman & Tjeerd J. Bouma. Historic storms and the hidden value of coastal wetlands for nature-based flood defence. 2020: Nature Sustainability: https://www.nature.com/articles/s41893-020-0556-z

17. Arne Pettersen. NGI- rapport: Overvåkning av forurensning av mudring og deponering. / NGI report: Monitoring of pollution of dredging and landfill. Endelig oppsummering 2014, revidert versjon 3. november 2015/ Final summary 2014, revised version 3 November 2015. 2015: http://www.renoslofjord.no/sfiles/94/64/4/file/20051785_59_rev0_final.pdf

18. Eli Rinde, Elin T. Sørensen, Mats G. Walday, Camilla With Fagerli, Hartvig Christie, André Staalstrøm, Line Johanne Barkved, Henry Simmons, Harald Bonaventura Borchgrevink (2019). *Utredning av aktuelle områder og tiltak for reetablering av biologisk mangfold i Oslos havnebasseng (Restoration of biological diversity of Oslo's urban sea areas)*. Norsk institutt for vannforskning & Norges miljø- og biovitenskapelige universitet. Contract No.: NIVA 7426-2019: https://niva.brage.unit.no/niva-xmlui/handle/11250/2631547

19. Bjørvika Utvikling. Art projects: Future Library and Losæter: Bjørvika Utvikling Anne Beate Hovind & Vibeke Hermanrud; 2020. Available from: https://www.bjorvikautvikling.no/portfolio-item/art-projects/

20. Andreas Treu, Katrin Zimmer, Christian Brischke, Erik Larnøy, Lone Ross Gobakken, Foued Aloui, Simon M. Cragg, Per-Otto Flæte, Miha Humar, Mats Westin, Luisa Borges & John Williams. Durability and Protection of Timber Structures in Marine Environments in Europe: An Overview. BioResources. 2019: 14(4): 24.

21. Elisabeth M. A. Strain, Karen Alexander, S. E. Kienker, Rebecca Morris, Rebecca Jarvis, Ross A. Coleman, Barbara Bollard, Louise B. Firth, Antony M. Knights, Jonathan H. Grabowski, Laura Airoldi, Benny Kwok Kan Chan, Suyin Chee, R. Coutinho, R. G. De Menezes, M. Ding, Yun-wei Dong, Clarissa M. L. Fraser, Aina G. Gomez, Jose Juanes, P. Mancuso, Luciana V. R. de Messano, L. P. D. Naval-Xavier, Steven Scyphers, Stephen E. Swearer, Paloma F. Valdor, J. X. Y. Wong, J. Yee & Melanie J. Bishop. Urban blue: A global analysis of the factors shaping people's perceptions of the marine environment and ecological engineering in harbours. Science of The Total Environment. 2019: 658: 1293-305. DOI: https://doi.org/10.1016/j.scitotenv.2018.12.285

22. Elin T. Sørensen, Eli Rinde, Camilla With Fagerli, Hartvig C. Christie, Mats G. Walday, Karl Jon Sørlie, Anne Beate Hovind & Sindre Langaas (2019). Urban Underwater Landscape and Tidal Gardens – is it Possible to Transform Seafloor Deserts in Oslo Harbour to Underwater Oasis? In *The 12th International Temperate Reef Symposium*. Hong Kong January 6-11, 2019 https://www.researchgate.net/publication/340950580_Urban_underwater_landscape_and_tidal_gardens_-_is_it_possible_to_transform_seafloor_deserts_in_Oslo_Harbour_to_underwater_oasis

23. Eli Rinde & Elin T. Sørensen (2019, September 19). *Mind the Gap – the Blue Common. Uncovering and Improving the Urban Blue*. The International Federation of Landscape Architects IFLA World Congress 2019 "Common Ground," Oslo 18-20 September.

24. Eli Rinde, Elin T. Sørensen & Trond Haraldsen (2019). *Anbefalinger tilknyttet planer for etablering av nye landskap ved Lakseberget og Telenor-stranda på Fornebu. En uttalelse fra*

et tverrfaglig fagforum opprettet av Bærum kommune (Statement and recommendations on plans for establishing new landscapes at Lakseberget and Telenor beach at Fornebu). Norsk institutt for vannforskning, Norges miljø- og biovitenskapelige universitet & Norsk institutt for bioøkonomi. https://niva.brage.unit.no/niva-xmlui/handle/11250/2624215

25. Ministry of Climate and Environment. (Act of 19 June, 2009). *Nature Diversity Act. Chapter I Purpose and scope*. Section 1. Available at: https://www.regjeringen.no/en/dokumenter/nature-diversity-act/id570549/ (accessed: April 5, 2020).

26. ByBi (2019). The Pollinator Passage. Available at: http://bybi.no/the-pollinator-passage/ (accessed: October 10, 2019).

27. Paul Gribben, Christine Angelini, Andrew H. Altieri, Melanie J. Bishop, Mads S. Thomsen & Fabio Bulleri. Facilitation Cascades in Marine Ecosystems: A Synthesis and Future Directions. Leiden: CRC Press; 2019: https://www.taylorfrancis.com/books/e/9780429026379/chapters/10.1201/9780429026379-3

28. Wenting Chen, David N. Barton, Kristin Magnussen, Ståle Navrud, Kristine Grimsrud, Per A. Garnåsjordet,Erik Engelien, Anne O. Syverhuset, Trine Bekkby & Eli Rinde. Verdier i Oslofjorden: Økonomiske verdier tilknyttet økosystemtjenester fra fjorden og strandsonen. 2019: https://niva.brage.unit.no/niva-xmlui/handle/11250/2627097

29. Robert E. Bowen, Michael H. Depledge, Cinnamon P. Carlarne & Lora E. Fleming. Oceans and Human Health: Implications for Society and Well-Being: Wiley; 2014.

30. Lora E. Fleming, Niall McDonough, Melanie Austen, Laurence D. Mee, Michael Moore, Philipp Hess, Michael H. Depledge, Mathew White, Katja J. M. Philippart, P. Bradbrook & Alexander J. Smalley. Oceans and Human Health: A rising tide of challenges and opportunities for Europe. Marine Environmental Research. 2014: 99: 16-9. DOI: https://doi.org/10.1016/j.marenvres.2014.05.010

31. Tytti P. Pasanena, Mathew P. White, Benedict W. Wheeler, Joanne K. Garrett & Lewis R. Elliott. Neighbourhood blue space, health and wellbeing: The mediating role of different types of physical activity. Environment International. 2019. DOI: https://doi.org/10.1016/j.envint.2019.105016

32. Karine Gagnon, Eli Rinde, Elizabeth G. T. Bengil, Laura Carugati, Marjolijn J. A. Christianen, Roberto Danovaro, Cristina Gambi, Laura L. Govers, Silvija Kipson, Lukas Meysick, Liina Pajusalu, İnci Tüney Kızılkaya, Johan van de Koppel, Tjisse van der Heide, Marieke M. van Katwijk & Christoffer Boström. Facilitating foundation species - the potential for plant-bivalve interactions to improve habitat restoration success Journal of Appl Ecology. 2020: 57: 1161–79. DOI: https://doi.org/10.1111/1365-2664.13605

33. European Commission (2015). *Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities: Final report of the Horizon 2020 expert group on Nature-based solutions and re-naturing cities*. Luxembourg: Directorate-General for Research and Innovation. Available at: http://dx.publications.europa.eu/10.2777/765301 (accessed: 15.02. 2015).

34. The City of Oslo Planning and Building Services & The Agency of Urban Environment. (2020). *Aktiv vannflate — en mulighetsstudie om bruk av fjorden (An active water surface)*. The City of Oslo: https://innsyn.pbe.oslo.kommune.no/saksinnsyn/showfile.asp?fileid=8902556&jno=2020012184

35. White Architects, Rodeo Architects & Marius Grønning. Havnepromenaden i Oslo. Forslag til prinsipp- og strategiplan. 2014. Pp 50.

36. BlueHealth. (2020). The BlueHealth project has received funding from the European Union's Horizon 2020 research and innovation programme. The programme involves specialists from countries across the EU and runs from January 2016 to June 2020. Available at: https://bluehealth2020.eu/ (accessed: January 3, 2020).

37. Palmgren, Hesselkrans, Hovind & Sørensen (2018). Professional dialogue between Michael Palmgren, CEO Marine Education Center Malmö, Åke Hesselkrans, caseworker at The City of Malmö, urban planner Anne Beate Hovind and landscape architect Elin T. Sørensen in Malmö, August 8, 2018.

Supporting information

Table 1. Critical factors for marine biodiversity identified in the 'rewild study' (18).

FACTOR	WHY THE FACTOR IS LIMITING
TERRAIN FEATURES	
Depth	Port developments transforms the natural rocky shore and soft bottom habitats into steep, hard edges, and deep soft seafloor. When the interventions lower the seafloor, the light conditions at the seafloor are reduced. As light drives photosynthesis, increased depth results in lowered growth conditions of photosynthesizing species like algae and seagrasses. Macroalgae and seagrasses form productive, species-rich blue forests and meadows. Hence, a deepening below the light threshold level for the individual plant species result in an absence of these blue forests and meadows. This again results in a lack of hiding places and food sources for the marine animals.
Slope and overhang	Steep surfaces generally create worse growth conditions for plants than more gently sloping surfaces. Algae can to a limited extent live on steep surfaces and beneath overhangs. Such landscape features are however to a less degree exposed to sedimentation and are often colonized by filtering animals.
Edge design	Smooth structures provide little habitat variation, and thus the basis for low biodiversity. Except from retrofit-solutions, habitat enhancing measures may be hard to integrate on massive quays with granite-fronts, or other large, heavy stone materials, as it may be seen as too costly to restore to a natural habitat.
Landscape diversity	Straight and uniform artificial seafront edges, do not offer the same landscape variation as the natural shoreline, neither regarding the horizontal nor vertical shore formations.
Fragmentation	Modifications and interventions in natural habitats caused by urban development may result in fragmentation and lack of necessary connectivity within coastal ecosystems. For example, shallow coastal areas are very productive and important nursery areas for fish. Urban development in such areas reduces the extent of nursery areas and possibly the connection between these and nearby spawning areas.
GROWTH SURFACES	
Access	Lack of suitable growth surface, either in form of hard or soft bottom at different depths, are a direct cause of lack of species that need a surface to settle on.
Type	Different types of growth surfaces promote different organisms and different levels of diversity. For example, natural stones with irregular surfaces and cavities between the stones provide better living conditions than smooth, straight steel pillars.
Grain size	Artificial urban beaches usually consist of one or a few grain sizes, thus promoting a reduced diversity compared to a natural beach that often offers a variation in grain sizes, from boulders to fine sand, and a variety of shells.
Complexity	Uniform surfaces and structures hamper biodiversity. Conversely, varied surfaces and structures, such as cracks, crevices and cavities of different sizes, contribute to an increased and more varied range of living areas/niches.
DISTURBANCES	
Boat traffic	Boat traffic may cause physical dislodgement of organisms due to e.g. waves. Further, boat traffic may cause resuspension of sediment particles and the spread of environmental toxins, as well as creating noise above and below water.
Introduced species	Artificial structures in the sea may promote the presence of alien marine species, which often are generalists and less selective in choice of habitat than native species. Harbors and marinas are particular important for spreading non-native species, both from individuals attached on the ship hulls, but also because of discharges of ballast water. Non-native species can cause extensive ecological and economic damage to aquatic ecosystems.
Fishing	Fishing from the quays is a valuable recreation activity in Oslo. At the same time, lobster fishery represents a threat to the city's marine biodiversity. Overfishing of lobsters was a key to the failure of an earlier marine diversity enhancement measure in Oslo. Lobsters are a key renovator at the seafloor, hence establishment of a lobster sanctuary might be a key to succeed in promoting marine life in this city.
Littering	Urban sea areas are exposed to litter, for example through leakage of the raw material for industrial plastic production, like small plastic pellets also called "mermaid tears." These are found in large quantities on the shores of inner Oslofjord, along with fishing ropes, Q-tips, plastic bags, drinking bottles, bikes, tires etc.
Erosion	During heavy rainfall events, eroded sediments are transported from land into the sea, both from rivers and from coastal areas, causing browning and silting that hamper photosynthesis and the living conditions for both algae and animals.
Sedimentation	There is extensive sedimentation of particles in the inner Oslofjord, which cover the seafloor, rocky habitats, marine plants and animals. In many areas the sedimentation rate is too high for plants and animals to thrive.
Building activities	Building and construction work result in noise, littering and increased rate of sedimentation into the sea.
Nutrient load	The discharge of nitrogen from the sewage into the inner Oslofjord is increasing because of increased human population. Furthermore, the wastewater treatment is not able to handle the large amount of water masses after heavy rainfall. Excessive nutrient loading results in blooms of phytoplankton, poor lighting conditions and oxygen deficiency when the algae break down on the seabed.

Supporting information

Table 1. continues.

FACTOR	WHY THE FACTOR IS LIMITING
Pollutants	New environmental toxins enter the sea from sewage and runoff from land. Moreover, leakages of contaminants from old fillings, agriculture, road traffic and industry, constitutes treats to the marine organisms, and particular to the animals.
Particles	Murky and turbid water contributes to poor lighting conditions that inhibit the growth of algae and eelgrass, which is dependent on photosynthesis.
Resuspension of particles	Resuspension of sediments caused by boat traffic causes turbid water and poor living conditions for plants and animals in the sea.
Ocean sprawl	Bridges, seawalls and floating pontoons etc. in the sea shade and hence contribute to reduced lighting conditions for life below water.
OXYGEN DEFICIENCY	
Low rate of water exchange	Due to a low degree of renewal of bottom water, combined with high nutrient levels, there are periodic problems with low oxygen levels on the seabed in several places at the seafloor of the Oslofjord.
Nutrients	Supply of nutrients stimulate the growth of plankton algae and filamentous algae, which require oxygen to be decomposed. Hence increased nutrient loading lead to lower oxygen levels.
Global warming	Change in temperature due to global warming increases the metabolism and oxygen demand of plants and animals. This may reinforce the problem of poor oxygen conditions in the future, in the context of expected climate scenarios.
Reduced water exchange	Buildings, piers and other structures into the sea may reduce water circulation and lead to reduced oxygen conditions. Under such conditions, the low-oxygen- water will have little opportunity to be replaced with oxygen-rich water.

Table 2. Overview of possible solutions to avoid, reduce or mitigated the limiting factors for marine biodiversity, identified in the 'rewild study' (18).

FACTOR	PROBLEM	POSSIBLE MEASURES
TERRAIN	Too deep	Build up and "lift the seabed up into the light" where possible. This will create living space for plants that need light and that create their own ecosystems with high biological diversity. Establishment of hanging marine gardens will have a similar effect as lifting the seabed to shallower areas with good light conditions for growth.
	Too steep	Build varied terrain that is similar to the natural beach zone, with both steep, s loping and flat terrain.
	Edge design	To repair established edges so that they promote biological diversity. Through offers of *three-dimensional habitats* in the sea, and *marine nature-based solutions*.
	Landscape diversity	Build new marine landscapes that mimic the natural shoreline's diversity of structures and growth surfaces, both in the coastal zone and on the deep seabed. Use nature-based solutions for the establishment of beach formation mimicking the rocky shore.
	Fragmentation	Measures to create ecological and landscape connectivity in Oslo's urban sea areas can build on experiences from the establishment of a pollinator passage and pollinator strategy on land.
GROWTH SURFACES	Lack of growth surfaces	Place different types of growth surfaces at several depths. For example, stones with or without rockweed can be moved from the nearby environment to the restoration area. Similarly, it is possible to establish eelgrass beds by moving eelgrass plants, including the sediments around the roots and the animals that live in the eelgrass community, to establish underwater gardens. Offer *three-dimensional habitats* in the sea, and *nature-based solutions*.
	Lack of the right type of growth surface	Choose types of growth surfaces that promote marine biological diversity, for example, steel is less suitable than local natural stone and/or marine life-friendly concrete.
	Low diversity in grain sizes	Uniform grain size gives low diversity. To promote biodiversity, a greater variety of rock sizes from large blocks to fine sand and silt will make a positive contribution. When establishing new marine landscapes, finer sand and sediments should be dammed up by larger rocks to prevent sediment escape and erosion.
	Uniform surfaces	Repair established uniform structures and surfaces such as pillars, quaysides etc. through the provision of *three-dimensional habitats* in the sea, and *nature-based solutions*.
DISTURBANCES	Waves from boat traffic	Waves from boat traffic can make a positive contribution to plants and animals in the coastal zone by creating water movements that increase the nutrient supply to algae and food particles to filtering animals. Too much wave action (such as the tsunami effect from large boats) can lead to detachment of species and turbulence of sediments (see below).
	Noise on and in the sea	Underwater noise is a problem that is receiving more attention in recent years and is considered the most problematic for marine mammals and fish. Noise that reach land is annoying to people. Electrification of motorboats and sailboats without a motor are some noise-reducing possibilities. The same applies to reducing / limiting time for land use of aggregates for large cruise ships.
	Resuspension of sediment and spread of environmental toxins due to boat traffic	Fewer and smaller boats in marinas will alleviate the turbulence of sediments with environmental toxins in the marinas. When developing in the sea, covering sediments with clean sand and using silt curtains are established methods. The use of *nature -based solutions* such as the establishment of eelgrass beds, edge vegetation that binds sediments will counteract the turbulence of sediments. Mussels and/or tunicate curtains can filter and capture particles. Boat sharing schemes can reduce the number of boats and thus turbulence of sediments in small marinas. E-boats will prevent the amount of petrol / oil spills from small boats. Own measures in marinas to deal with pollution from boat cleaning are central.
	Introduced species	Like on land, measures must be taken at sea to avoid the spread of alien species at the expense of native species.
	Fishing	Lobster protection zones and restrictions on the capture of key species that have important functions in the constructed and re-established ecosystems should be established. Crabs and lobsters play an important role in cleaning the bottom of dead mussels and other organisms.
	Littering	Dissemination, clean-up actions and maintenance are necessary to solve various waste problems. One possibility is to train underwater gardeners with the main responsibility for clean-up and care. Collection and deposit schemes for rubbish can be developed.
	Erosion	Secure sand and gravel landfills on land close to shore. Establish buffer vegetation on land and undersea. Stabilize landfills by using *natural erosion protection* based on *nature-based solution*.
	Sedimentation	Interventions such as dredging should be done in a gentle way that reduces the spread of sediments. *Integrated urban water management* will reduce problems with sedimentation. An overview of surface water courses is required. *Natural erosion protection* measures will contribute to fewer particles reaching the sea.
	Construction activities	Mitigation measures to avoid and reduce noise and supplies of waste and sediments from construction must be planned. Avoidance of plastic should take place at production level. Placement of silt skirts etc. is important. Critical phases in the construction process that place a strain on natural values should be monitored visually and by using e.g. turbidity meters, and critical phases for animals such as spawning time for cod and birds' breeding periods must be avoided.
	Nutrient load	Upgrade and increase the capacity of the treatment plants in line with population growth. Urban onshore water management is required. Several strategies and guidelines have been drawn up for this, including the establishment of *natural erosion protection* measures.
	Environmental toxins in runoff from land	Reduce runoff from hard surfaces on land by means of *integrated urban water management* and *nature-based solutions* such as rain beds, sand pits, natural erosion protection, biotope roofs etc.
	Environmental toxins from «old sins»	Clean-up of waste and illegal landfills. Covering contaminated sediments is an established method of avoiding the spread of environmental toxins from old discharges on the seafloor.
LIMITING ENVIRONMENTAL PARAMETERS		
Light access	Murky water	Reduce the supply of humus and particles in runoff from land through *integrated urban water management* and *nature-based solutions*. Reduce the supply of nutrients that stimulate the bloom of planktonic algae. This involves upgrading sewer pipes and treatment plants. Implement rain beds, catch ponds, sand traps etc.
	Shading constructions	Provide light measures in constructions. Minimum light requirements can be set for jetties and floating structures in the sea. Shade from high-rise buildings should be considered in each development. *Diversity-promoting habitat* associated with floating structures such as floating islands, bridges for pedestrians, boat docks is possible.

FACTOR	PROBLEM	POSSIBLE MEASURES
Lack of oxygen	Poor water circulation	Physical measures that create waves, currents or agitation of water masses, i.e. measures that increase water circulation. *Nature-based solutions,* as establishing or promoting blue forests, like seagrass beds and kelp forests, will improve the oxygen conditions.
	Too much nutrients	*Integrated urban water management* and *nature-based solutions* such as blue forests and filtering animals will purify and filter the water for nutrients.
	Global warming	Choose measures that promote species that are able to withstand the expected temperature increase over the next 20-50 years. Blue forests have been shown to have a climate-suppressing effect and to buffer against acidification by producing oxygen. Thus, the establishment of vegetation has a dampening effect during heat waves due to global warming.
	Reduced water circulation	When building into the sea, requirements should be set for modeling the structures impact on waves, currents and oxygen conditions. Where it is possible, structures can be modified and/or measures that increase water circulation can be implemented.

Appendix II

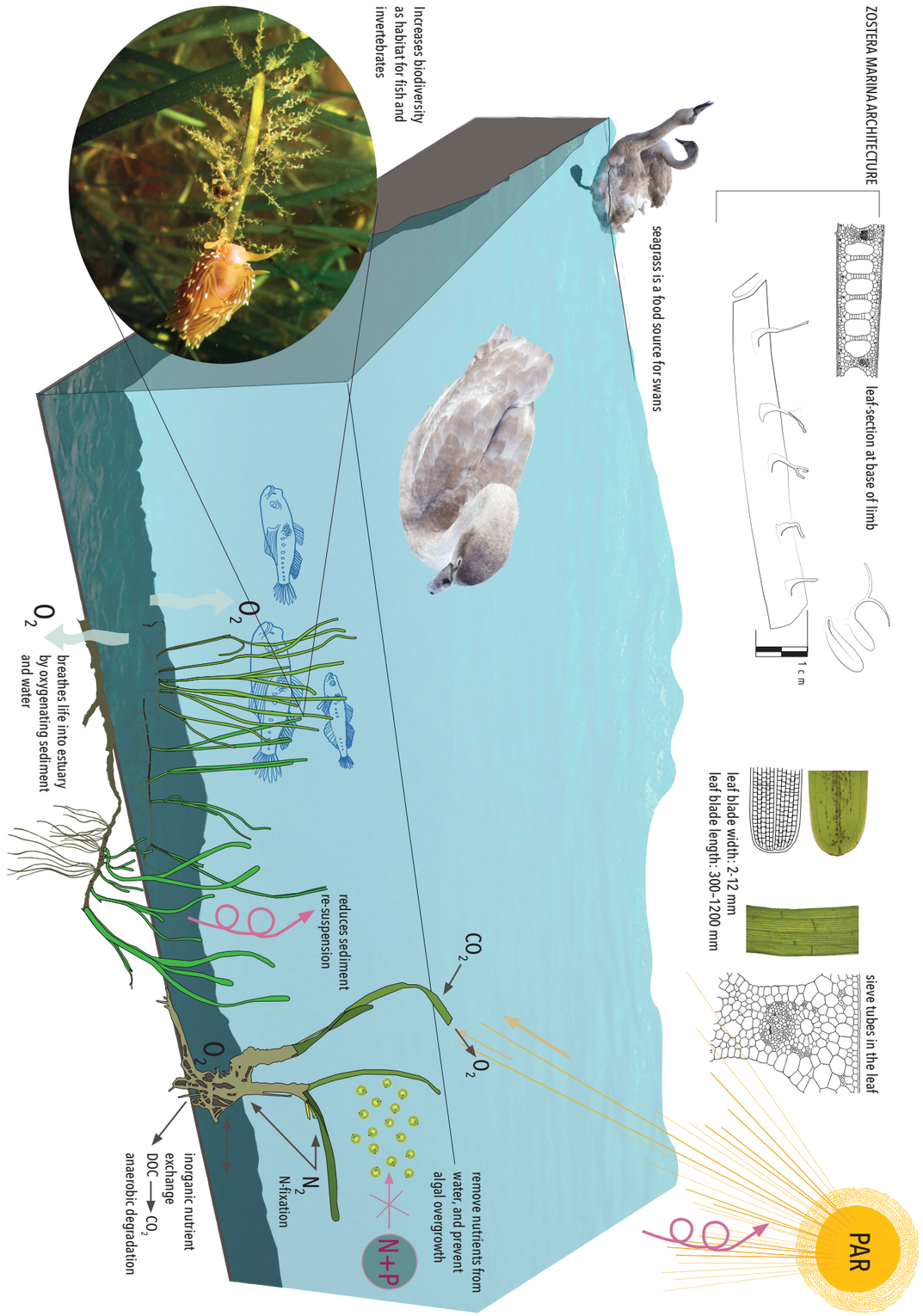
Contents

185—186 On marine nature types

187—189 Summary of the NIVA and NMBU reports

190—193 On the thesis' living blue-lab initiatives

194—199 Four practical examples of waterscape eco-engineering at a landscape scale



On marine nature types

Knowing the influence of topography, sediments and ecological processes in marine environments are important prerequisites for being able to create dynamic tidalscapes in urban sea areas. To achieve viable marine communities, it is recommended to combine sand and soft bottom habitats with hard bottom habitat features. One option is to facilitate for soft bottom habitats by creating depressions by arranging local rock material or marine friendly building materials so that sand and mud are kept from being washed away by the movement of *water:* like waves, tides, and *currents*. Another option is to supplement or create new environments by prefabricated solutions such as concrete lobster houses with surface textures or other prefabricated textured surfaces that mimic rocky shore habitats.

The list below includes a short presentation of nature types and key-areas of relevance for repairing and improving the urban intertidal of the inner Oslofjord. In the following, these marine habitats are highlighted in bold and grouped according to their belonging in either soft- or hardbottom communities. Soft bottom refers to a seabed dominated by soft substrate such as sand or mud. The term hard bottom relates to a seabed dominated by stones and bedrock that typically occur along the shore where wave action prevents sand and silts to remain. In some areas, the two substrate types coexist in a small-scale mosaic pattern. The natural variation in structure and texture within these systems give a multitude of ecological niches.

Shallow soft bottom habitats

Shallow soft bottom areas often comprise of mudflats and sandflats from which the seawater withdraws at low tide, consisting mainly of fine grain sediments with some larger boulders. Banks where sandy sediments occur in a layer over hard substrata are classed as sandbanks if the associated biota is dependent on the sand rather than on the underlying rock. Mud- and sandflats are of importance as feeding grounds for wildfowl and waders. The diverse intertidal communities of invertebrates and algae that thrive here are, by example, eelgrass communities or brackish water vegetation close to estuaries. **Eelgrass meadows** (*Zostera marina*) are vital to a range of species and play a vital role in maintaining sediment and water quality. Eelgrasses are in strong decline globally, yet they are not considered as threatened in Norway. They have for a while been proposed as a selected habitat type, which would give it a stronger protection status. However, this initiative was never finished and concluded. The conservation of eelgrass beds is at times in conflict with coastal construction works like dredging, urbanisation and marinas. **Spawning grounds for fish** are key ecological function areas, that are often found within eelgrass meadows. Species such as trout also depend on well-function riverscapes where they can travel freely, and which offer good spawning habitats. An **estuary** forms an ecological unit with the surrounding terrestrial coastal habitat types.[1]

Opposite page: properties of eelgrass (*Zostera marina*). Diagram by Elin T. Sørensen © BONO 2018: Underwater photo of eelgrass with nudibranch and hydroid by Eli Rinde (NIVA). Photos of swans and microscope images of eelgrass by Elin T . Sørensen. The diagram is based on figure in "Seagrass" by The Department of Water and Environmental Regulation, Australia[2] and Ugarelli et al. 2017, p. 13 (fig. 1).[3]

1 (European Commission Environment Directorate, 2019; Miljødirektoratet, 2007; Rinde & Sørensen, professional dialogues 2016–ongoing)
2 (The Department of Water and Environmental Regulation, 2018)
3 (Ugarelli et al., 2017)

Hardbottom communities

Reefs are hard compact substrata, such as rocks, boulders and cobbles, arising from the seafloor on solid and soft bottoms in the sublittoral and littoral zone. These hardbottom habitats house benthic communities of marine animals, concretions, encrustations and corallogenic concretions, together with red, brown and green algae — where some live on the leaves of other algae. The term biogenic concretions comprise for example, oyster reefs and mussel beds. **Native oyster reefs** (*Ostrea edulis*) are formed by oysters colonising rocks or shells in the intertidal down to 5 meters. **Tide pools** found in depressions along the rocky shore can be looked upon as small seas in miniature where seawater is trapped by the receding tides. Here, variation in oxygen content and pH occur with a diurnal cycle that differs from chemical and physical fluctuations in the surrounding sea. A specific trait of these small seas is their 'heating system': Rain from above, or other freshwater supply forms an enclosing layer on top of the salty pool, eventually causing a rise in temperature. Thus, these miniature concavities favour heat-tolerant species. On the tide pool walls, interstitial spaces on the surface — that is very small gaps — provide 'air pockets' and room for Lilliputian sediment carpets. This nature type provides sheltering spaces for inhabitants such as snails, barnacles, mussels, anemones, urchins, sea stars, crustaceans, seaweed, and small fish. Blue mussel-beds (*Mytilus edulis*) and boulder habitats for Shore crab (*Carcinus maenas*) and Common lobster (*Homarus gammarus*) are some ecological functional areas having informed this thesis design-works.[4]





Left: blue mussels often form aggregations, attaching to each other with strong silky byssus threads. Right: Tidal pool at Hovedøya. Photos by Elin T. Sørensen © BONO 2018/2019.

References

European Commission Environment Directorate (2019). Appendix 1–Marine Habitat types definitions. Update of "Interpretation Manual of European Union Habitats" Natura 2000 in the Marine Environment: European Commission Environment Directorate. Available at: https://ec.europa.eu/environment/nature/natura2000/marine/docs/appendix_1_habitat.pdf (accessed: June 3, 2020).

Miljødirektoratet (2007). Kartlegging av marint biologisk mangfold. DN-håndbok 19-2007, May 31, 2007.

Miljødirektoratet (2013). Littoralbaseng. Available at: http://www.miljodirektoratet.no/no/Tema/Miljoovervakning/Kartlegging-av-natur/Kartlegging-av-naturtyper/Marine-naturtyper/Oversikt-marine-naturtyper/Littoralbaseng/ (accessed: December 15. 2018).

NOAA (2019). What is a tide pool? Available at: National Ocean Service website https://oceanservice.noaa.gov/facts/tide-pool.html (accessed: April 27, 2020).

Norwegian Environment Agency (2013). Marine naturtyper: Norwegian Environment Agency. Available at: https://tema.miljodirektoratet.no/no/Tema/Miljoovervakning/Kartlegging-av-natur/Kartlegging-av-naturtyper/Marine-naturtyper/Oversikt-marine-naturtyper (accessed: March 10, 2018).

Rinde & Sørensen (2016-2020). Professional dialogues between marine biologist Eli Rinde and landscape architect Elin T. Sørensen, during the period of the doctoral study 2016-2020.

Kelly Ugarelli, Seemanti Chakrabarti, Peeter Laas and Ulrich Stingl (2017). The Seagrass Holobiont and Its Microbiome. Microorganisms, 5 (4) (81): 28. doi: https://doi.org/10.3390/microorganisms5040081

UK Marine (2001). Physical gradient. Available at: UK Marine SACs Project http://www.ukmarinesac.org.uk/communities/intertidal-reef/ir2_1.htm (accessed: November 15. 2018).

4 (European Commission Environment Directorate, 2019; Miljødirektoratet, 2013; NOAA, 2019 ; Norwegian Environment Agency, 2013; Rinde & Sørensen, professional dialogues 2016–ongoing; UK Marine, 2001)

Summary of the NIVA and NMBU reports

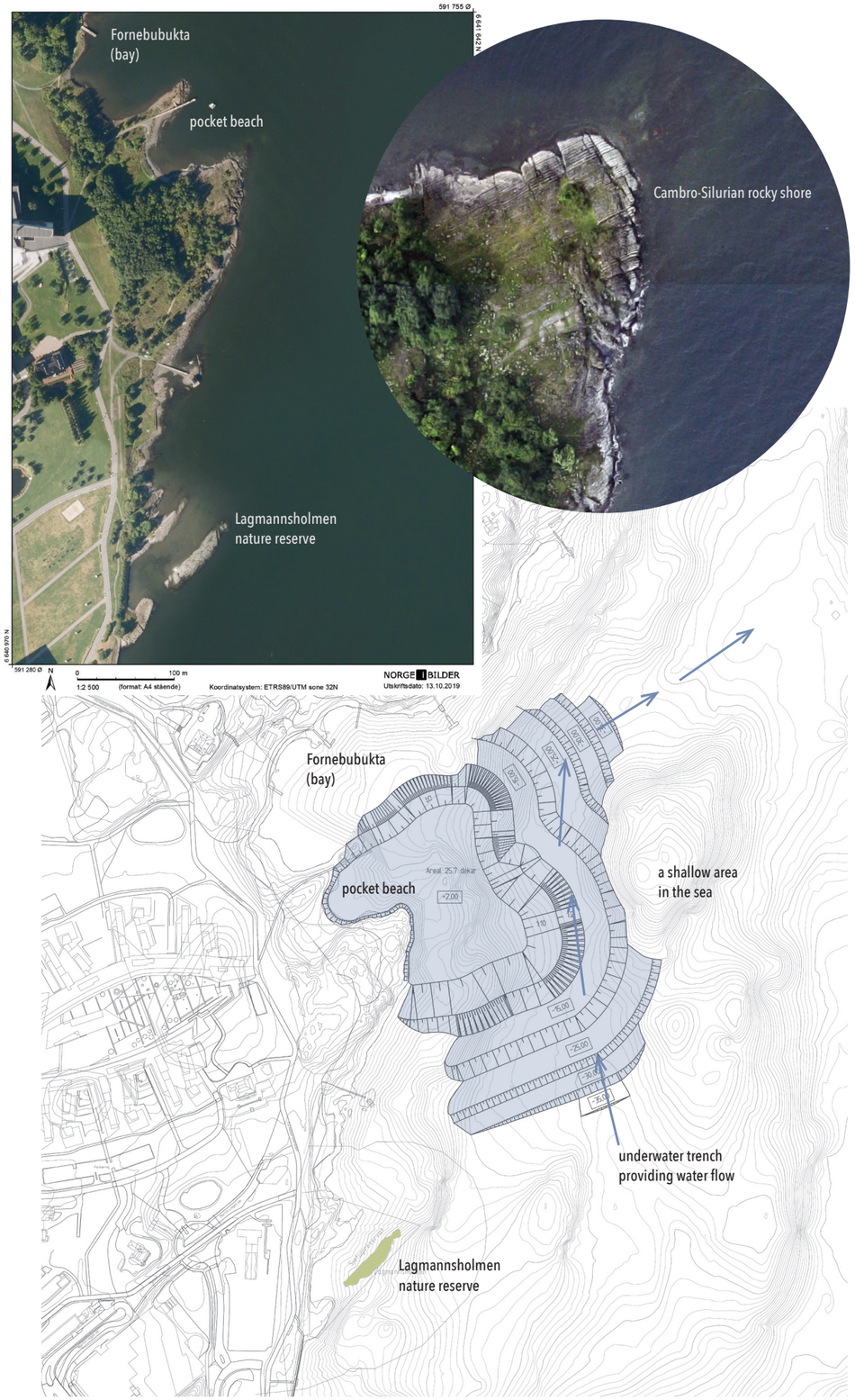
Rewilding the Fjord City

"Restoration of biological diversity of Oslo's urban sea areas" is a cross-disciplinary report made on behalf of the Agency of Urban Environment and Oslo Waterfront Planning Office. In this work, and cross-disciplinary team consider possible measures to maintain and increase the biodiversity of Oslo's urban sea areas. A field study from 21 sites between Frognerstranda and Kongshavn/Grønlia, gave an overview of the current state. This, together with previous surveys and involvement with diversity-promoting actions, informed a cross-disciplinary ideas-workshop on possible solutions for rewilding the Fjord City.

The work evaluated the limitations of the areas with respect to biodiversity, and mitigation measures for improved conditions of the fjord. The most important limiting factors were related to terrain and growth surface characteristics, light access, nutrients, oxygen, environmental toxins, and other disturbances due to human impact. For restoration purposes, the team focused on direct diversity-promoting actions such as repairing the urbanised shoreline and the deployment of diversity-promoting habitats. Additionally, the team proposed means preventing and reducing disturbances related to excessive nutrients, environmental toxins, water circulation, and poor lighting conditions. The recommendations emphasize viewing the area from a landscape-scale management perspective, by the creation of good marine neighbourhoods through the establishment of species that promote each other's presences. This could be done by restoring existing communities or by planting habitat forming species. This may create what is called a *facilitation cascade*, which means that marine plants and animals that form habitats themselves also promote another habitat-forming species. In sum, this type of interactions has positive effects on local biodiversity.

Today's shoreline in the study area is categorized as either *uniform design of fillings along the shore*, or *uniform design of developed shoreline*. To separate between different restoration methods and types of solutions, we created different categories for restoration and establishment of new marine communities in the Fjord City. Measures belonging to a landscape-scale management perspective, was collected under *diversity-enhancing reparation of the developed shoreline*. Further, large-scale restoration measures facilitating for marine life through integration of marine life-friendly materials, structures and textures on buildings and infrastructure along the foreshore and in the shallow sea zone, was collected under the term *diversity-enhancing marine landscape architecture*. In the Norwegian context, this is a new and innovative approach. These large-scale interventions may include different landscaping solutions. For example, an organic shoreline formation that mimics the natural shoreline's variation and design in horizontal and vertical directions, as well as its geological diversity. Other applicable small-scale solutions were termed *diversity-promoting and three-dimensional marine habitats* that embrace many opportunities. Including *hanging marine gardens*, *blue forests* and *communities of filtering animals* as mussels (*Mytilus edulis*) and flat oysters (*Ostrea edulis*). Altogether, these fall within *nature-based solutions* where ecological functions help to stabilize, purify and enrich the environment. One example of this is natural erosion protection measures where plant roots help to keep sediments in place and provide oxygen to soil, water and air. The latter is a central solution for an *integrated urban water management*, along with green walls and biotope roofs, vegetation buffer zones by water, rain beds, permeable covers, sand catches and other solutions interacting with the urban hydrological cycle.

Based on the field survey and a workshop together with participants from the Agency of Urban Environment and Oslo Waterfront Planning Office, we describe the Fjord City prevailing foreshore design and current status for factors limiting marine biodiversity. Finally, we provide input on what is required to develop a comprehensive and long-term strategy to conserve and increase the biodiversity of Oslo's urban sea areas. Also including possible dissemination measures that can further the understanding of the importance of having a living fjord. Achieving the necessary knowledge of native species and local environmental conditions, require deep collaboration across fields and between stakeholders, testing of diversity-promoting methods, mapping and monitoring of marine life, light and oxygen conditions, runoff, toxins etc.



The inner harbour area is well-suited for connecting data collection from various measurement sensors to environmental monitoring programs already established within the inner Oslofjord. A way forward lies in conducting feasibility studies assessing the potential for successful implementation of life-enhancing-measures for marine organisms at the recommended sites. With respect to reparation of the urban shoreline by local use of rock materials from large infrastructure projects, one must collaborate across municipal boundaries.

Eli Rinde, Elin T. Sørensen, Mats Gunnar Walday, Camilla With Fagerli, Hartvig C. Christie, André Staalstrøm, Line Johanne Barkved, Henry Simmons and Harald Bonaventura Borchgrevink (2019). *Restoration of biological diversity of Oslo's urban sea areas*. Oslo: NIVA & NMBU, October 2019. Report 7426-2019.1.

Marine landscaping and land reclamation from use of local rock materials

The report "Statement and recommendations on plans for establishing new landscapes at Lakseberget and the Telenor-beach at Fornebu" was commissioned by Bærum municipality. The municipality assembled a cross-disciplinary forum to evaluate plans for local use of the large amount of surplus rock materials generated from major infrastructure projects. The plans concern possible biodiversityenhancing actions by the Fornebu-beach and Lakseberget marina in Sandvika.

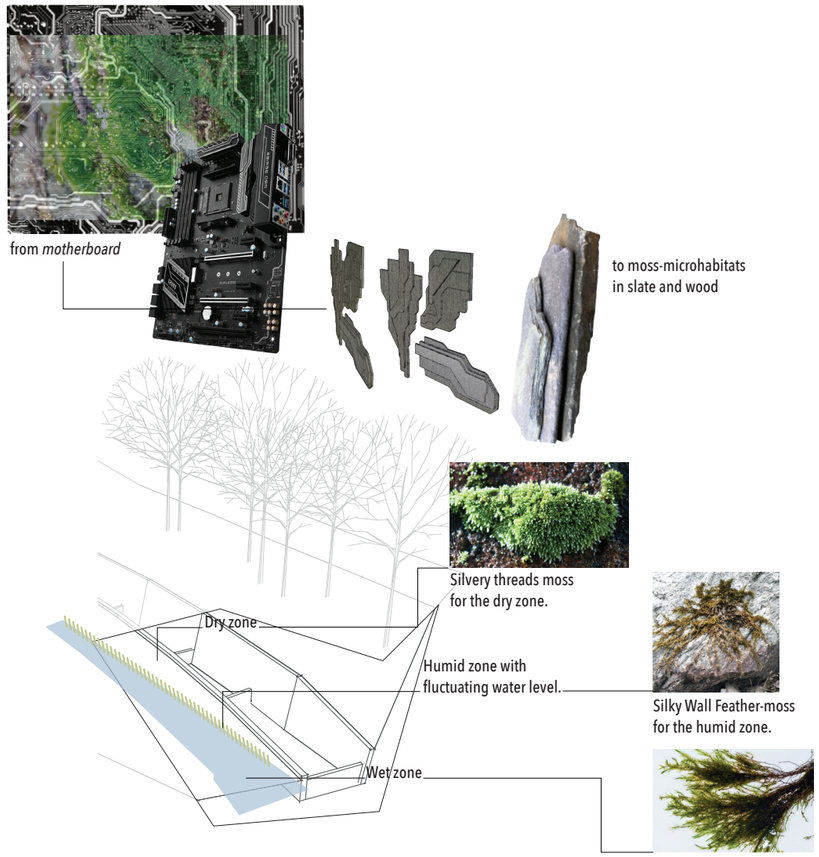
In a time of higher environmental consciousness, attention needs to be drawn towards the re-use of excavated materials from tunnelling and road constructions. Reclaiming landscape qualities by local use of rock materials in the sea and in fresh water has great potential as nature improvement actions in areas that need repair, presuming the work is site-sensitively done, and if geography, topography and ground conditions are suitable for such disposal. The municipality has conducted thorough investigations of the sites and has commissioned reports for several relevant environmental research topics. The forum's assessments are based on this material in addition to the members' prior knowledge of the sites and involvement with blue-green diversity-promoting actions. In the recommendations, the forum emphasized the location, design and implementation of the proposed re-naturalization in compliance with the purpose of the Nature Diversity Act "to protect biological, geological and landscape diversity and ecological processes through conservation and sustainable use, and in such a way that the environment provides a basis for human activity, culture, health and well-being, now and in the future."[2] In addition to evaluating the two sites, the forum provides general recommendations and advice on how local use of rock materials can be used to return disturbed and/or develop coastland to an improved state enhancing biodiversity and recreational values. The report describes potential benefits from urban wildlife restoration by means of comprehensive land use planning that facilitate for outdoor activities, water-sports and boating as well as connecting educators to the shoreline.

On the planned artificial island "Friluftsøya" in Lysakerfjorden: The plans involve a large, irreversible intervention within a unique Cambro-Silurian geotope comprising great biological, geological and landscape values, as shown on the opposite page. Conditions which in addition enriches the place as an outdoor recreation area. Based on the knowledge of the forum, there is no need for biodiversity-enhancing actions in the area as the site appears intact.

On the restoration of Lakseberget: As the site is already heavily modified, Lakseberget needs repair and could benefit from land reclamation. Creating a biotope-enhancing landscape by local use of rock materials from the large amount of surplus rock masses, that also include outdoor recreational spaces, is considered a sustainable solution.

Eli Rinde, Elin T. Sørensen and Trond Haraldsen (2019). *Statement and recommendations on plans for establishing new landscapes at Lakseberget and the Telenor-beach at Fornebu*. Oslo: NIBIO, NIVA & NMBU, November 2019. Report 7419-2019.3.

1 (Eli Rinde et al., 2019b, p. 7-8)
2 (Ministry of Climate and Environment, Act of 19 June, 2009)
3 (Eli Rinde et al., 2019a, p. 6)



Time and succession	Mosses have a slow growth rate and spontaneous colonization may take time. The application of growth mixtures composed of moss particles mixed with nutrients will facilitate establishment, and accelerate growth. Assumingly, at least one growth season is required before any substantial results and the moss-colonization of surfaces are in general uncertain. The development depend much on access to water. To document the colonization over time, points for photography will be established where pictures are taken on a regular basis.
Moisture availability	Mosses are generally divided into two groups according to drought-tolerance and species that avoid drought. To ensure that the species applied can withstand the stressful environment and periods of drought, we advice drought-tolerant mosses thriving directly on rock surfaces for this environment. Good water availability and / or high humidity optimizes growth. Assumingly, natural watering from the stream is sufficient for the mosses as regular water spray will provide a stable water regime. Textures like angles, cavities and crevices provide microclimate conditions beneficial in terms of moisture.
Texture	Irregular surfaces enhance natural colonization and microhabitat reliefs will help the moss particles to settle as the spores and vegetative material will not be flushed away from rainfall or for other reasons. To monitor the development of different species a wall zonation for the moss tapestry is applied: adapted to different growth requirements.
Materials	Variation in materials allows several species to thrive, which is essential in a long-term perspective and for the emergence of new species. Mosses have great variation in form and colour: like silver-moss (*Bryum argenteum*) or the brownish as great hairy screw-moss (*Syntrichia ruralis*). The design desire to facilitates for variations in textures, colour and contrast as the pattern unfolds.

Example of wall zonation for a moss tapestry for a fluvial retention wall.
Diagram by Elin T. Sørensen © BONO 2017.

On the thesis' living blue-lab initiatives

The thesis' co-developed living-lab initiatives address local adaption by means of incorporating essential features of coastal habitat diversity, like local foundation species. The aim is to create liveable environments for nonhuman others that is also beneficial to city dwelling people. This implies extending the blue-green infrastructure undersea and enhancing the city's biological performance through an ecosystem approach. From 2017 to the present, some of the study's co-creators and I have launched such initiatives in the Fjord City. The core-group includes marine biologist Eli Rinde, urban developer Anne Beate Hovind and me in cooperation with diverse stakeholders, referred to as the urban intertidal team. Paper #3 of this thesis is informed by these efforts and introduces a stepwise process including three main phases in an urban blue habitat framework for arriving at living blue-labs. Regarding this, the initiatives shortly presented below are all examples of a preparatory phase. To to extract a few essential processual features. One is the role of public outreach. The other is that to achieve multifunctional marine neighbourhoods, consideration for marine creatures must be included in the master planning from the earliest phases.

Moss-microhabitats along Gaustadbekken

The very first design experiment happened throughout 2017 with the development of the artwork "Mosses/circuits;" This was an entry to an open idea's competition on behalf of Oslo City Water and Sewage Works Agency. "Mosses/circuits" was co-created with Magni O. Kyrkjeeide, a botanist specialising in mosses and reseacher at The Norwegian Institute for Nature Research (NINA).

The main task was to adapt viable moss-microhabitats for a fluvial retention wall supporting the re-opened stream Gaustadbekken running through the Oslo Centre for Interdisciplinary Environmental and Social Research (CIENS). One question underlying the experiment, was how to facilitate moss growth through the creation of microhabitats that mimics natural moss environments, and which will work well on a long-term basis. The other was how to turn a conventional retention wall into a contemporary artwork involving living material?

Lessons learned and present status: Regarding the slow growth rate of mosses, we suggested a longer time frame for the development than the client wanted, and our proposal was rejected. Concerning the communication of results, the methodological set-up for the artwork "Mosses/circuits" is presented in the paper "On urban hard surfaces," published in the Nordic Academic Press of Architectural Research, 2018.[1]

An eelgrass growth trial in Lohavn

The main task involved planning for the transplantation of eelgrass (*Zostera marina*) from a nearby meadow as a small-scale biodiversity enhancement experiment at Lohavn. The question was whether this marine plant could thrive within a sheltered industrial port environment like Lohavn. This area is one of the Commons in Bjørvika. The experiment was proposed as a temporary event within the ongoing redevelopment. The trial was contextually related to the site close location to the art project "Flatbread Society/Losæter." This artwork, commissioned and produced by Bjørvika Utvikling, was also established as a temporary event. Today, Losæter has grown into a new cultural institution, dedicated to a range of activities related to art and urban food production.[2] In this regard, besides experimenting with the growth of eelgrass, we sought conveying the ethnobotanical aspects: such as the practical uses of this plant according to traditional knowledge of different cultures.

Process, co-creators and interaction events: The growth trial was initiated by the urban intertidal team, and hence, carried out as an Ad-hoc experiment to the ongoing master planning. The plan was to grow eelgrass in wood-pallets with a nod to the urban farming on land. The boxes were intended to be suspended from the remaining concrete dock, at three levels in order to study if and at which depth level the plants could thrive, in the murky urban sea water.

1 (Sørensen, 2018, pp. 425-428)
2 (Bjørvika Utvikling, 2020)

Eelgrass was to be harvested from local populations with a portion of the natural growth substrate. As eelgrass is considered as a vulnerable marine habitat type, the transplantation of eelgrass from a local population, triggered the need to apply for a permit from the County Governor. The experiment was not implemented due to the developer's cancellation (cf. the section "*Re/acting* in the Fjord City" in Part III), and we never got feedback on the status of the application. The project preparatory phase was running from February until August 2018. Besides the voluntary effort from the urban intertidal team, developers from Bjørvika Infrastructure (BI), marine biologist Hartvig C. Christie (NIVA), and divers from Project Baseline Oslo were involved. During the planning, timber technologist Dr. Andreas Treu at the Norwegian Institute of Bioeconomy Research (NIBIO) joined as an advisor. More, by discussing the eelgrass transplantation with a caseworker at Viken County Council, I was introduced to the City of Malmö's urban eelgrass projects described in Part III.

Lessons learned and present status

From being involved in this experiment, we gained unexpected knowledge regarding the idea of submerging wood-boxes into the sea, as they would never have endured wood-degrading organisms like marine wood-boring species.[3] Due to this, Treu's research on timber in marine environments will be part of the collaborative coastal community art project "Under/sea," that has evolved during the course of this thesis as described in Part III.

The main lessons learned was a common awareness of several problems related to choices of material for establishing submerged seagrass beds, how to perform eelgrass transplantation and the required formalities. To carry out such a complex experiment outside the ordinary planning process contribute to uncertainty. More, the time-limit for this case was too short to result in a viable solution. Eventually, the experiment was not implemented due to the developer's cancellation. To conclude, timing and a robust interaction platform are some success factors.



To the left and in the middle: the shipworm's (*Teredinidae*) valves. Shipworms are notorious for boring into, and commonly eventually destroying, wood that is immersed in sea water. To the right: a wood piece after being submerged four months in the inner Oslofjord. Microscope photo and photo reprinted by permission from Andreas Treu (NIBIO). Photo of shipworms inside a sliced wood piece from Alchetron Free Social Encyclopaedia for the World.

New residential quartiers in Bispevika

The main tasks in developing a demo-case for Bispevika was facilitating for hard and softbottom communities within the submerged part of the new housing quartier. The process, including the co-creators and lessons learned are retold in Part III, in the section "So close to seeing an undersea-lab come alive in Bispevika" and in paper #3 in Appendix I.

3 (Treu et al., 2019)

A temporary industrial blue park at Kongshavn

During 2018-2019 I was involved in a collaboration with The Project Development and Construction Group Skanska to develop a feasibility outlining the potential for a temporary industrial blue parkland at Kongshavn. My concept reflected the site character in-between port, industry and city centre. In scope was Skanska's interest in piloting climate friendly technology and solutions for an intermediate storage facility for rock materials from major infrastructure projects in the Oslo region. This assignment was due to the activities at the Facebook Community "Kongshavn Bad:" Among other things, some of the directors of the Port of Oslo real estate company who collaborated with Skanska had become aware of this blog.

Process, co-creators and interaction events: To accommodate the need for public recreation spaces by the shore, the task was to design a path running along the landfill headland. The question was how to innovatively merge nature-based solutions and recreational values in combination with the handling of surplus rock materials. One idea was a vegetation strategy based on the Oslofjord flora was promoted: based on plants growing at Hovedøya and Bleikøya. Another was to make biotope rooftops on the containers enhancing insect and birdlife. Yet another was the promotion of a generous vegetation buffer along the Alna river estuary that would contribute to natural erosion protection, better water quality and experiential quality. The Sidney Port transformation project "Barangaroo Reserve", described later in this Appendix, inspired the proposed landscaping regarding the way historical maps have guided the re-naturing of Sydney Harbor. Through the Kongshavn-case, I got the chance to promote nature-based solutions and speak up for the urban intertidal, among other reaching neighbours to the site, caseworkers at the Oslo Waterfront Planning Office, and Directors at the Port of Oslo. The Kongshavn work-team included Hans Petter Johannessen district manager at Skanska Industrial Solutions, urban planners from Norconsult, urban developer Anne Beate Hovind, and Directors at the Port of Oslo real estate company.

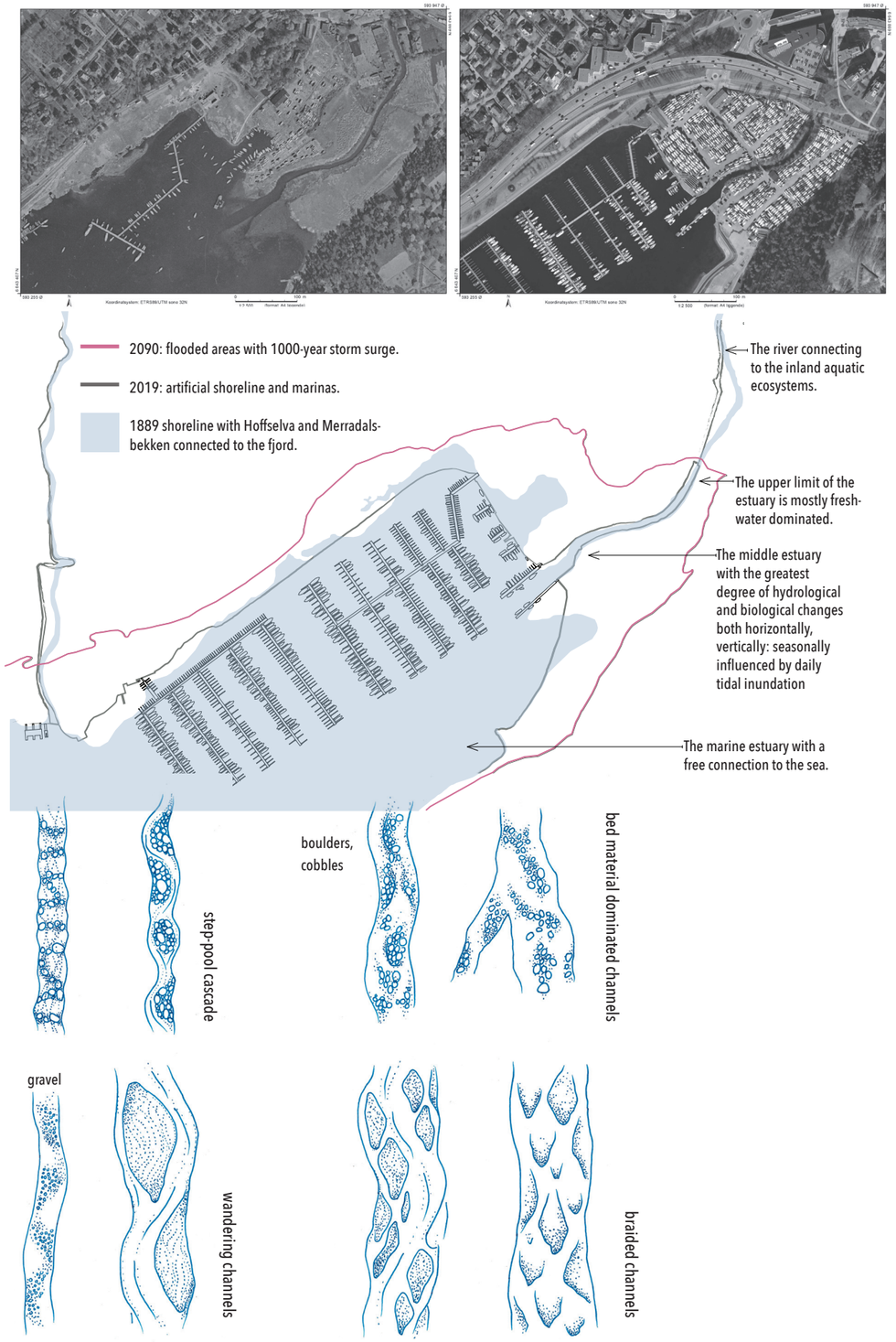
Lessons learned and present status: Due to the City of Oslo Planning and Building Services' principle not to include industrial activities close to city-centre settlements, the application for a temporary permit was rejected: the anticipated climate-friendly best practice of mass management and nature-based initiatives didn't leverage. An outcome of this process was the co-developing of a pilot vegetated raft as part of the concept for a temporary industrial blue park at Kongshavn. The results are described in Jostein Rykkelid's mentioned Master thesis.

References

Bjørvika Utvikling (2020). *Art projects: Future Library and Losæter*: Bjørvika Utvikling by Anne Beate Hovind and Vibeke Hermanrud. Available at: http://loseter.no/portfolio-item/art-projects/ (accessed: June 5, 2020).

Elin T. Sørensen (2018). On urban hard surfaces. In Toft & Rönn [Editors]. NAAR Proceedings Series, vol. 1 *The Production of Knowledge in Architecture by PhD Research in the Nordic Countries*, pp. 411-435. Nordic Academic Press of Architectural Research.

Andreas Treu, Katrin Zimmer, Christian Brischke, Erik Larnøy, Lone Ross Gobakken, Foued Aloui, Simon M. Cragg, Per-Otto Flæte, Miha Humar, Mats Westin, Luisa Borges and John Williams (2019). Durability and Protection of Timber Structures in Marine Environments in Europe: An Overview. *BioResources*, 14 (4): 24. https://bioresources.cnr.ncsu.edu/wp-content/uploads/2019/10/BioRes_14_4_Treu_REVIEW_Durability_Protection_Timber_Structures_Marine_14995-2.pdf



Above: Bestumkilen 1956/2019 including the 2090 high water line: an area with potential for an amphibious tidalscape.
Below: river morphology and riverbed material transport with step-pool cascade, wandering channels and braided channels. Hand-drawn sketches by Elin T. Sørensen © BONO 2020, informed by Church (2006), based on the concept of Mollard (1973) and Schumm (1985).
"Bed Material Transport and the Morphology of Alluvial River Channels," p. 330 (fig. 2) in Annual Review of Earth and Planetary Sciences.

Four practical examples of waterscape eco-engineering at a landscape scale

There are still few realized examples of holistic practices of enhancing the urban intertidal as a unified landscape. The compilation of information included below, is a way of connecting to ongoing urban development trends involving the marine environment and waterscapes. These projects clearly demonstrate that such innovative efforts must build upon collaboration between a broad set of professionals and stakeholders — not least the watery world and its inhabitants.

The river as the "landscaper"

The Renaturation of the River Aire has influenced this thesis' perspective by the ingenious way of letting the waterscape design itself freely. In allowing for an interplay between the bed material and water flows to create wandering channels, a naturally adapted riverine landscape emerges over time. The landscaping is a marvel in the way in which the team listens to and honours the waterscape dynamics. Instead of restoring the riverscape to its natural state the team "did exactly the opposite by preserving the traces that man had left on the landscape over the preceding decades. It made a forward-looking contribution to landscape development and harmoniously juxtaposed recreation and ecology, while also providing an answer to the topical question of how landscapes should develop near ever more densely populated urban areas."[1] To incorporate this knowledge into practice, the technique of creating braided channels has been tested in visualisations for the possible re-naturing of the river Alna and Hoffselva's urban estuaries.

PROJECT DATA

Project: Renaturation of the river Aire, Geneva.[2]

Client: République et Canton de Genève (State of Geneva).

Landscape Architecture: Georges Descombes and Atelier Descombes & Rampini, urban and natural planning projects.

Architecture: Group Superpositions.

Engineers: B+C Ingénieurs ZS Ingénieurs civils.

Biology: Biotec SA.

Construction period: Chronology: Phase 1 2002–2006, Phase 2 2009 – 2011, Phase 3 2012–2015, Phase 4 ongoing.

Costs: Phase 1: 1'500'000 Fr. Phase 2: 25'000'000 Fr Phase 3: 33'000'000 Fr.

Length: 5 km. Surface: 50 Ha.

Awards: The 2015 Hasepreiss Gold/Landschaft. The 2012 Schulthess Award for gardens. Finalist for Rosa Barba Prize;
The Public prize at the 2016 Biennale of Landscape Architecture in Barcelona. The Council of Europe Landscape Award 2019.

2 (Federal Office for the Environment FOEN, 2019)
3 (Group Superpositions, 2016)

A coastal protection structure welcoming sunlight and wildlife

The Elliott Bay Seawall Project has informed of the thesis 3-D animations demonstrating a diversity-enhancing marine landscape architecture, such as the floating dock with a light-penetrating surface. The seawall project represents a landscape approach in connecting sea and land by the integration of diversity-promoting habitats in the coastal defence structure, combined with urban water management and road infrastructure at land. The inclusion of visual artists in developing urban intertidal design is likewise exemplary. This project is one of few examples of an integrated design practice in the interest of marine life. "The Central Seawall Project is unique among public realm projects due to the high level of collaboration between landscape architecture, civil/structural/marine engineering, infrastructure specialists, and aquatic habitat specialists. Innovative habitat creation is paired with integrated public realm design, which both contribute to the health of marine life while positively engaging the public in understanding all issues at stake."[3]

PROJECT DATA

Project: Elliott Bay Seawall Project[4]
Client: City of Seattle / Seattle Department of Transportation.
Urban Design / Landscape Architecture: Urban Design Lead James Corner Field Operations, Tatiana Choulika, ASLA, Principal.
Local Landscape Architects: Harrison Design Landscape Architecture & Architect Berger Partnership.
Artists: Haddad/Drugan, Laura Haddad (Seawall Panel 2). Ann Hamilton (Public Piers). Oscar Tuazon (Waterfront).
Buster Simpson (Pioneer Square). Norie Sato (Union Street).
Architecture: Miller Hull Partnership (Overlook Walk). Schemata Architects (Union Street). Weinstein AU (Washing Landings).
Graphics, Signage & Wayfinding: Tomato.
Project Management: Shields Obletz Johnsen, Inc.
Public Outreach: EnviroIssues.
Prime Firm, Program Manager, Design Manager, Permitting, Environmental Documentation, Procurement,
Program management, engineer of record: Parsons Corporation.
Planning, engineering, and environmental support: Tetra Tech on behalf of The Seattle Department of Transportation.
Construction Management: Jacobs Engineering Group Inc.
Lead Engineer for Public Realm, Habitat Design Integration and Overlook Walk: Magnusson Klemencic Associates. Engineering for Overlook Walk: Rushing.
Technical Lead: CH2MHill.
Engineering: Parametrix and Parsons Brinkerhoff.
Coastal Engineer: Moffatt & Nichol.
Civil and Drainage Engineer: Perteet & SvR.
Irrigation: Dragon Fly Irrigation.
Water Feature Specialist: Fluidity.
Engineering for Pool Barge: Aquatic Design Group.
Habitat Engineer: Hart Crowser.
Marine Research: Researchers from the University of Washington's School of Aquatic and Fishery Sciences Marine.
Structural Engineering: Bright Engineering. Additional Structural Engineers: COWI North America (formerly
Ben C. Gerwick, Inc.) & Exeltech Consulting, Inc. Geotechnical Engineer: Shannon & Wilson, Inc.
Marine mattress structural geogrid: Tensar © Integrally Formed Structural Ge.
Lighting Consultant: Dark Light. LPS panels: Custom fabricated by APS Architectural Prescast Structures, cast in place
concrete sidewalk. Tested by the LEPR, who analysed over 35 options and simulated light penetration levels with 3ds Max software.
Construction period: Construction on the new seawall began in 2013, was partly completed in 2017, and is ongoing.
Costs: $372 million / $410 million infrastructure project.
Area: 2.4 km (1.5 miles) of Seattle's Central Waterfront.
Awards: The ASLA Professional Awards in 2013 and 2017.

3 (The American Society of Landscape Architects ASLA, 2017a)
4 (Christensen, 2017; Iverson, 2019; James Corner Field Operations, 2013; Parsons, 2012; Seattle Waterfront Projects, 2017)

Building relationships between people and the sea

Living Breakwater and the Billion Oyster Project informed the thesis' concept-development regarding the inclusion of the public in neighbourhood events and activities such as guided class site visits to the Breakwaters, workforce development, oyster restoration and monitoring. The project's instructive visualisation of representative marine habitat types guided the 3-D visualisation of a diversity-enhancing reparation of developed shoreline, inspired by marine nature types found in the Oslofjord. "By combining a coastal resilience structure and habitat enhancement techniques with community engagement, Living Breakwaters advocates for a layered approach to risk reduction that extends offshore to inland, and avoids creating a wall between people and water. The Living Breakwaters design reduces risk, revives ecologies, and connects educators to the shoreline, inspiring a new generation of harbour stewards and a more resilient region over time."[5]

PROJECT DATA

Project: Living Breakwater and the Billion Oyster Project[6]
Client: NYS Governor's Office of Storm Recovery and U.S. Department of Housing and Urban Development.
Implementation: New York State Governor's Office of Storm Recovery.
Urban Design / Landscape Architecture: Team Lead SCAPE Landscape Architecture, with Kate Orff as Project Director.
Education/Oyster Restoration: The New York Harbor School.
Engineering and planning: Parsons Brinckerhoff.
Marine Science/Ocean Modelling: Dr. Philip Orton and the Stevens Institute of Technology.
Ocean & Coastal Consultants: SeArc Ecological Consulting.
Ecological Design: Dr. Shimrit Perkol-Finkel, Co-Founder and CEO, ECOncrete Tech Ltd.
Architecture: LOT-EK.
Graphic Design: MTWTF.
Engineers: MFS Consulting Engineers and Prudent Engineering.
Advisor/Author of "American Catch: The Fight for Our Local Seafood" (2014): Paul Greenberg.
Partners: The Billion Oyster Project, New York Harbor School, the Tottenville Civic Association, the Tottenville Historical Society,
the NY/NJ Baykeeper and the city Parks Department.
Construction period: The project planning began in 2013, and the construction in 2018 – ongoing.
Costs: $60 million of CDBG-DR funding allocated specifically for this project.
Area: Area is not disclosed.
Awards: The project was part of the MoMA Rising Currents Exhibition in 2010, resulting in a $60 million implementation grant to build the protective reef structures. Winner of the 2014 Rebuild by Design Competition. Recipients of the Buckminster Fuller Challenge Award grand prize 2014, a $100.000 grant supporting the development and implementation of one outstanding strategy for solving some of humanity's most pressing problems. The project was refined as part of President Obama's Hurricane Sandy Rebuilding Task Force Rebuild by Design initiative. Receiving the ACEC NY Engineering Excellence Award, and the National Achievement Award for Environmental Planning in 2015.

5 (The American Planning Association APA, 2017)
6 (Cohen, 2015; Jewell, 2014; Keag, 2017; Rebuild by Design, 2015; SCAPE, 2014; The American Society of Landscape Architects ASLA, 2017b)





From "Landscapes with a Soul," above: Frognerkilen in 1881 with a soft shoreline and the wetland area "Tyskerstrand." Below: A proposed amphibious tidalscape with wetland, blue forests and the Frognerelva reopened. Stills from the animated pilot by Elin T. Sørensen, assisted by Runa Tunheim © BONO 2019-2020.

A water edge where all your senses are engaged

The creation of the pilot animation "Landscapes with a Soul," follows a search for the landscape deep structure. The video feature landscape transformation around Bygdøy from 1624, the eventual land uplift, until the predicted future storm surge return heights of 2090. In the Barangaroo Reserve project, the visual geography of Sydney Harbor is restored through the creation of a nature like shorepark. The landscaping demonstrates a "revival of Sydney Harbor's historic headland that rebuilds a long-lost connection to the pre-colonial past while creating an active, naturalistic, environmentally sensitive civic space, serving both people and animals, on the land and in the water. The design of the headland includes a dramatic foreshore of 10.000 sandstone blocks excavated directly from the site, an elegant and dramatic way of bringing back a landform important to the original Aboriginal culture and a major element in the project's compliance with One Planet Living principles."[7]

PROJECT DATA

Project: Barangaroo waterfront renewal project that redefines Sydney Harbour and its Central Business District.
Client: Sydney Harbour/Barangaroo Delivery Authority.
General Contractor: Lend Lease (formerly Baulderstone Pty Ltd), Sydney, Australia.
Urban Design / Landscape Architecture: Lead Designer PWP Landscape Architecture in association with JPW.
Architect: WMK.
Quarry Operation and Chief Stone Mason: Troy Stratti.
Horticulturalist: Stuart Pittendrigh.
Soils Engineer: Simon Leake, SESL Australia.
Construction Observation: Tract Landscape Architects.
Civil and Structural Engineers: Robert Bird Group and Aurecon.
Hydraulic Engineer: Warren Smith and Partners.
Construction Management: Evans and Peck.
Marine Engineer: Hyder Consulting.
Geotechnical Engineer: Douglas Partners.
Traffic Engineer: Halcrow.
Lighting Engineer: Webb Australia Group.
Wayfinding and Signage: Emery Studio.
Historic Interpretation: Judith Rintoul.
History and Arts: Peter Emmett.
Landscape Contractor: Regal Inovations.
Plant Procurement Nursery: Andreasens Green.
Construction period: Started 2011-2012. The first phase in the 3-district master plan opened August 22, 2015.
Costs: Costs are not disclosed.
Area: 22-hectare waterfront renewal.
Awards: The Australian Institute of Landscape Architect (AILA) NSW Landscape Architecture Awards in 2016.
American Architecture Prize in 2017. The 2019 ASLA Professional Awards.

7 (The American Society of Landscape Architects ASLA, 2019)

References

Ken Christensen (2017). *Seattle's new seawall: Holding back the tide, protecting salmon*. Crosscut. Available at: https://crosscut.com/2017/05/seattle-seawall-salmon-protection (accessed: July 20, 2017).

Michelle Cohen (2015). *Living Breakwaters: An Award-Winning Project Brings 'Oyster-tecture' to the Shores of Staten Island*. 6sqft's. Available at: https://www.6sqft.com/living-breakwaters-an-award-winning-project-brings-oyster-tecture-to-the-shores-of-staten-island/ (accessed: February 3, 2017).

Federal Office for the Environment FOEN. (2019). *The Aire renaturation project wins the Landscape Award of the Council of Europe*. Federal Office for the Environment FOEN Available at: https://www.bafu.admin.ch/bafu/en/home/topics/landscape/dossiers/landscape-award.html.

Group Superpositions (2016). *Renaturation of the River Aire - Designing a rivergarden*. Available at: http://landezine.com/index.php/2016/06/renaturation-of-the-river-aire-geneva/ (accessed: August 30, 2016).

Beau Iverson (2019). *A New Seawall Anchors Seattle's Waterfront*. Seattle magazine. Available at: http://www.seattlemag.com/news-and-features/new-seawall-anchors-seattles-waterfront (accessed: April 10, 2019).

James Corner Field Operations (2013). *Seattle's Central Waterfront*. James Corner Field Operations. Available at: https://www.fieldoperations.net/project-details/project/seattle-central-waterfront.html (accessed: May 13, 2015).

Nicole Jewell (2014). *Resilient "Living Breakwaters" Project Wins Prestigious 2014 Buckminster Fuller Challenge* inhabitat. Available at: https://inhabitat.com/resilient-living-breakwaters-project-wins-prestigious-2014-buckminster-fuller-challenge/ (accessed: March 29, 2018).

Susan Lunny Keag (2017). *Living Breakwaters project: Can it protect us from future storms?* Staten Island Media Group Available at: https://www.silive.com/news/2017/03/living_breakwaters_find_out_ho.html (accessed: Novmber 13, 2018).

Parsons Corporation (2012). *Elliott Bay Seawall Project – Seattle, WA*: Parsons. Available at: https://www.parsons.com/project/elliott-bay-seawall-project/ (accessed: December 23, 2019).

Rebuild by Design (2015). *Living Breakwaters*. Rebuild by Design. Available at: http://www.rebuildbydesign.org/our-work/all-proposals/winning-projects/ny-living-breakwaters (accessed: March 5, 2016).

SCAPE (2014). *Living Breakwaters: Design and Implementation*. SCAPE Landscape Architecture Available at: https://www.scapestudio.com/projects/living-breakwaters-design-implementation/ (accessed: July 24, 2017).

Seattle Waterfront Projects (2017). *Seawall Project:* City of Seattle's Office of the Waterfront and Civic Projects. Available at: https://waterfrontseattle.org/waterfront-projects/seawall (accessed: May 15, 2018).

The American Planning Association APA (2017). *National Planning Achievement Awards 2015*. The American Planning Association Available at: https://www.planning.org/awards/2015/achievement.htm (accessed: December 19, 2019).

The American Society of Landscape Architects ASLA (2017a). *Central Seawall Project*. Available at: https://www.asla.org/2017awards/320768.html (accessed: May 5. 2018).

The American Society of Landscape Architects ASLA (2017b). *Living Breakwaters Staten Island, New York, U.S.A.* The American Society of Landscape Architects. Available at: https://www.asla.org/sustainablelandscapes/breakwaters.html (accessed: December 16, 2019).

The American Society of Landscape Architects ASLA (2019). *Barangaroo Reserve*. The American Society of Landscape Architects. Available at: https://www.asla.org/2019awards/641545-Barangaroo_Reserve.html (accessed: December 16, 2019).



Author's Biography

Elin T. Sørensen is a visual artist, animator and landscape architecture, trained in Norway, Finland and Estonia. Her practice involves site-specific concerns and co-creation with an emphasis on the ocean, ecological processes and the possible inclusion of nonhuman lifeforms. The artistic development unfolds on a slow-time basis to reflect the interactions and dialogues with landscapes, people, knowledge-fields and the species with which we share the environment: within this, the emerging artworks are often expressed as temporary situations where artefacts return to the original context or material cycle after completion.

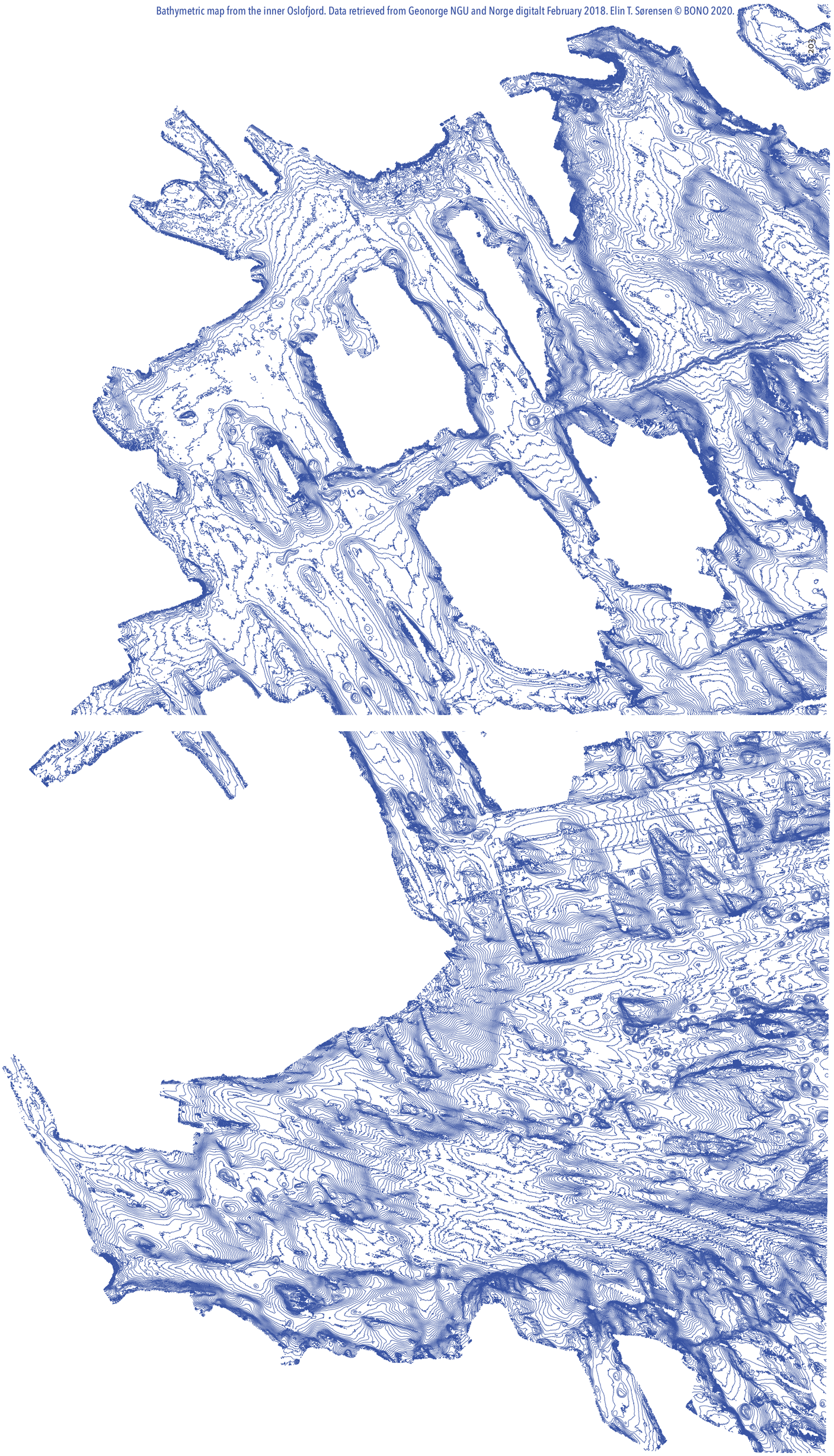
Her research interests include practice-based research in the arts and landscape architecture, urban sea areas and the urban intertidal, ecology and integrated urban water management, co-creational practices and more-than-human care.

Sørensen's work experience started within the arts after graduating from The Oslo National Academy of the Arts in 1999: practicing both as an experimental installation artist and a curator with a keen interest in sound art. After completing the Master Program at Landsam (NMBU) in 2008, she worked two years as a specialist advisor on sustainable urban planning at The Agency for Planning and Building Services, City of Oslo. Thereafter, working as a consultant in the private sector concerned with urban water management and nature-based solutions at Plan Urban and COWI Oslo respectively — before embarking on the PhD Program at Landsam in 2016. Sørensen founded the proprietorship Urban Living Laboratory in 2010, and today works as an artist and independent consultant specialising on a marine landscape architecture.

Education: 2016—2020 PhD-fellowship at The School of Landscape Architecture. Faculty of Landscape and Society (Landsam), Norwegian University of Life Sciences (NMBU). 2005—2008 Master Program at Landsam (NUMB) with a thesis on ecological sanitation and nature-based solutions. 2004—2005 Centre for Development and the Environment at the University of Oslo (UiO) including four weeks of fieldwork at The Centre for Science and the Environment (CSE) New Delhi, India. 1993—1999 The Oslo National Academy of the Arts (KHiO). 1997 Kuvataide Akatemia Helsinki: Department of Time and Space, Finland. 1995—1997 Volda University College, Faculty of Media and Journalism — Documentary Film and Animation, with an internship at Eesti Joonisfilm OÜ in Tallinn, Estonia.

Photo by William Olsson 2019.

Bathymetric map from the inner Oslofjord. Data retrieved from Geonorge NGU and Norge digitalt February 2018. Elin T. Sørensen © BONO 2020.



Multispecies Neighbourhoods in Urban Sea Areas

Philosophiae Doctor (Ph.D.) Thesis 2020 • 38

ISBN: 978-82-575-1702-1

ISSN: 1894-6402

Elin T. Sørensen

Faculty of Landscape and Society

Norwegian University of Life Sciences



This thesis is a call for attention, understanding and respect, offering multiple perspectives on marine habitats–providing a broad scope from creating awareness to changing the practice of actual waterfront development projects. As Elin Tanding Sørensen writes, "I have set out to unify the landscape between land and sea, both in people's imagination and by concrete designs for building into the sea in more inclusive ways."

The thesis establishes collaboration between the earth-bound and water-bound sciences and practices to overcome the disconnect and neglect towards the world under the "opaque surface" of the water. Ocean literacy is established as a prerequisite for a holistic practice to adequately conceive and create "Multispecies Neighbourhoods in Urban Sea Areas" when "building into a watery world."

This thesis is a model to draw from the disciplinary specifics of marine biology and ecology to be explored with artistic methods and practices–both for the sake of exploration and for representation and communication. In the best sense, of translation and interpretation, this thesis makes disciplinary knowledge comprehendible and relevant for a larger audience.