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MA Material Futures
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A Drop in the Ocean

How can we empower people in the deacidification of the oceans through waste-consumer behaviour ?

Summary

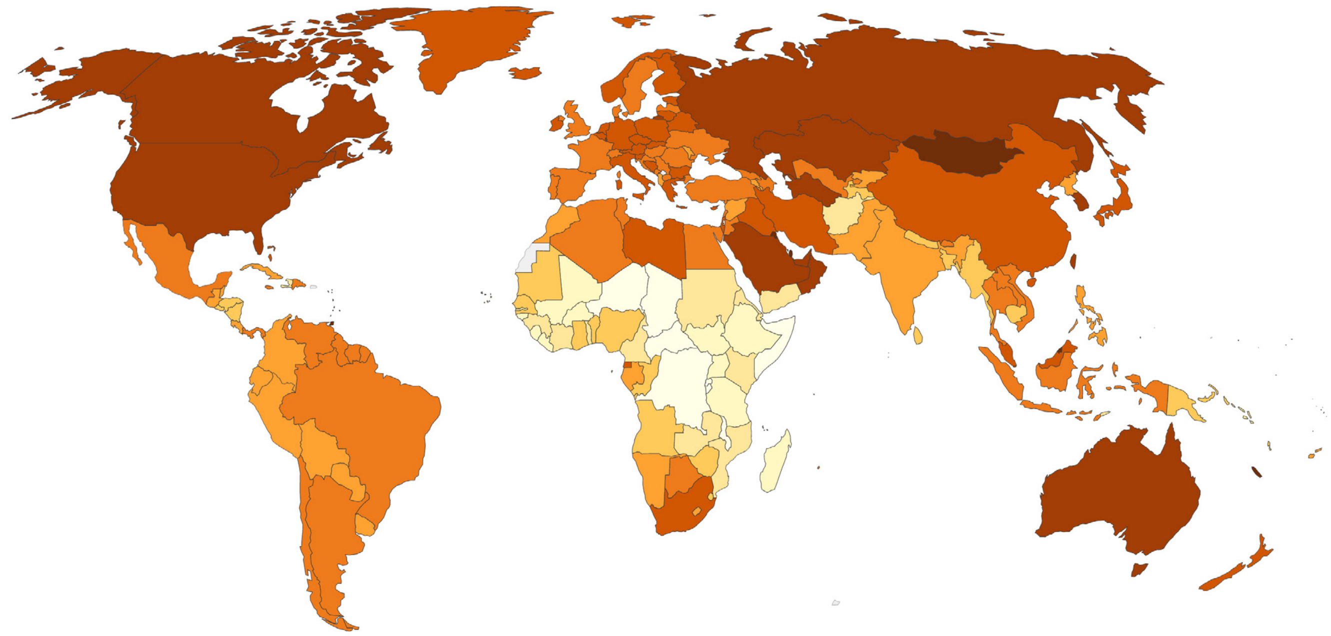
Introduction

Absorption of carbon dioxide by the ocean causes a lowering of the ocean's pH, with a 30% increase in ocean's acidity since the industrial era. Its effects are still mostly impacting marine life, not humans. However, communities relying on the fish industry are already seeing the negative impacts.

This project is a journey from a product design traditional approach, constantly seeking for ways to solve complex problems, whether it be global or local problems, to a more realistic way of viewing these complex global issues. What could we do to really prevent these ecosystems to collapse ? What are scientists doing and what could be done at an individualistic scale ?

How can functional needs for humans be coupled with the ocean ecosystems regeneration ?

Looking at different lenses of the issue of Ocean Acidification, I aim through this project to uncover the different elements causing this to happen and what are the impacts, from the root of climate change to the communities impacted by it.



CO2 per capita map, Our world in Data (2020)

1.1 Humans negative impacts

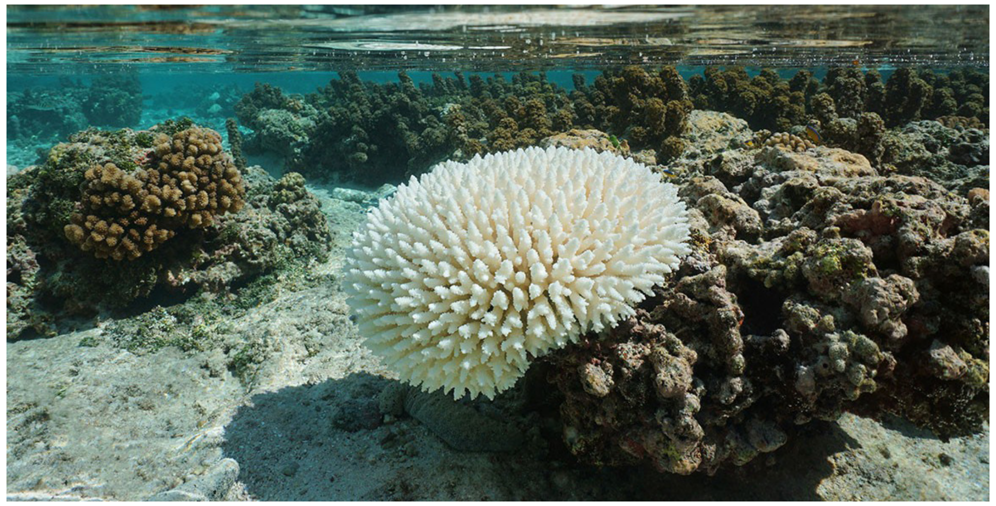
Due to humans constant search for comfort and the overuse of finite resources, marine and terrestrial ecosystems around the world are suffering from different industries made only for humans needs. Ecosystems are destroyed (i.e deforestation) or struggling to survive (ocean acidification, coral bleaching).

Whilst both terrestrial and marine ecosystems are threatened by global problems such as global warming, GHGs, over concentration of CO_2 in the atmosphere, most researches and efforts made to tackle issues related to global ecosystems present and futures were made around "terrestrial" ecosystems.

This is due to humans relating more to terrestrial ecosystems, themselves being terrestrial species. Another factor which adds to this is the scale of the problems humans are trying to "solve" : oceans, compared to terrestrial ecosystems such as forests, prairies or deserts, seem too large and global at a human scale.

fig.1
An amusement park in Southend beach, an example of humans trace in natural environements
S.Ramaherison (2022)

fig.2
Coral bleaching event at the great barrier reef



 Thus, a first question arises : Can we really solve the global environmental problems we have caused to the world ? The simple answer would be no : according to the 2022 GIEC report, global temperatures are expected to rise by 1.5°C as early as 2030, ten years earlier than the IPCC's previous forecast.The IPCC is looking at five scenarios and the most pessimistic one predicts a warming of between 3.3 and 5.7°C.

 But we can prevent future environmental problems and ease Earth's "life" mainly by cutting CO2 emissions, thus shifting our current doings and habits from a consumerism approach towards a more sustainable approach. Where should we start ? How much impact could a single person have on the global environment state ?

"Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions." IPCC,2013: 17

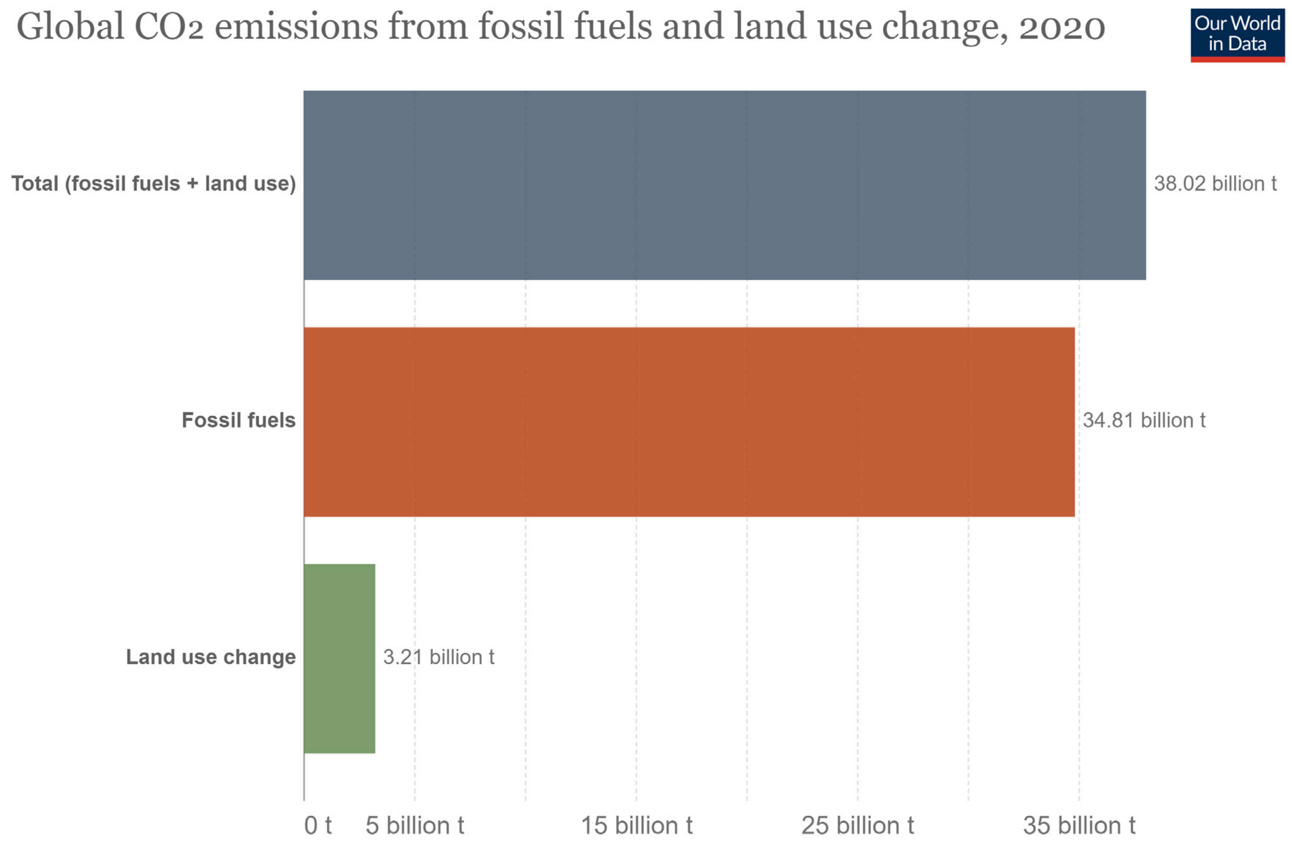
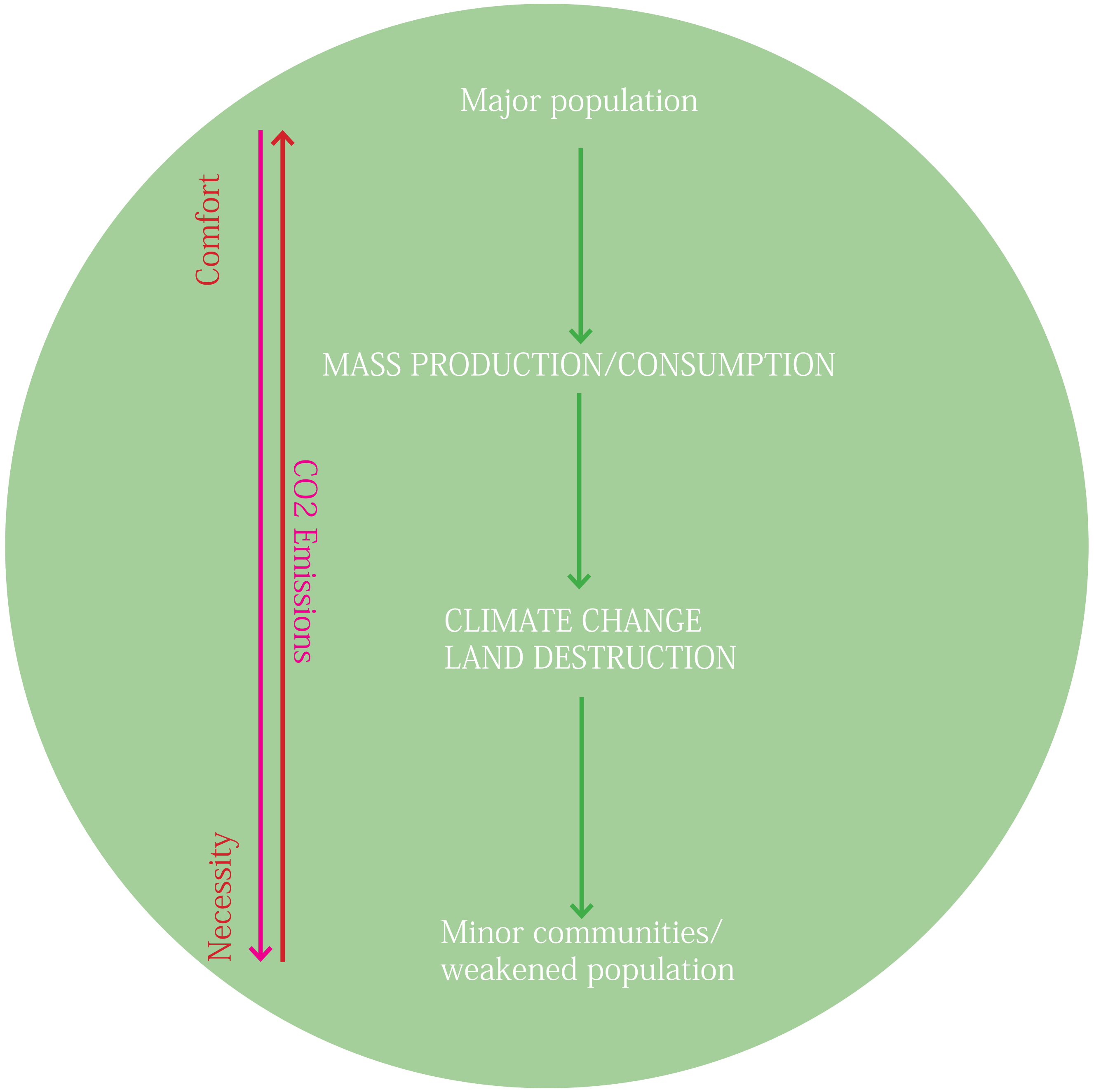


fig.3 Global carbon project diagram (Our world in data, 2020)

From simple system design thinking, I deducted that we should start from the root of the problems :



This is where we can observe how much impact a single human could have negatively on the Planet, when scaled to a large number.
While Australia is on 20.6 tonnes per person (partly because of its reliance on CO_2-intensive coal) and the UK is half that at 9.7 (explained in part by relatively CO_2-light gas power stations), India is on a mere 1.2.
Poorer African nations such as Kenya are on an order magnitude less again – the average Kenyan has a footprint of just 0.3 tonnes (a figure that's likely to drop even lower with the country's surge in wind power).

The root of the problem being the overuse of fossil fuels, and overproduction, how can we stop industries from producing more and using these finite materials ?
Would a single person have enough power to reduce or stop these doings ?

> "(The) little exercise in individual self-limitation could have revolutionary implications if it were transferred to people around the world – regardless of their origin or social status."
>
> – Tools for the Design Revolution, Institute of Design Research Vienna, 2014

After this comparison on terrestrial and oceanic problems differences, I chose to research more on what are current oceanic issues and what we should expect from the future.

- As a starting base, I used a diagram (fig.5), where Ocean Acidification is already impacting Southern part of Madagascar, where fishermen have to shift from their fishing job to agriculture, but as they are also impacted by drought, most agricultural practices rely on slash-and-burn practices, which helps fertilizing soils for a short period of time but overtime will damage crops and release more CO2 in the atmosphere.

- Other problems emerging from our negative impacts are coral bleaching – increased ocean temperature caused by climate change, runoff and pollution, Storm generated precipitation can rapidly dilute ocean water and runoff can carry pollutants, causing coral bleaching –

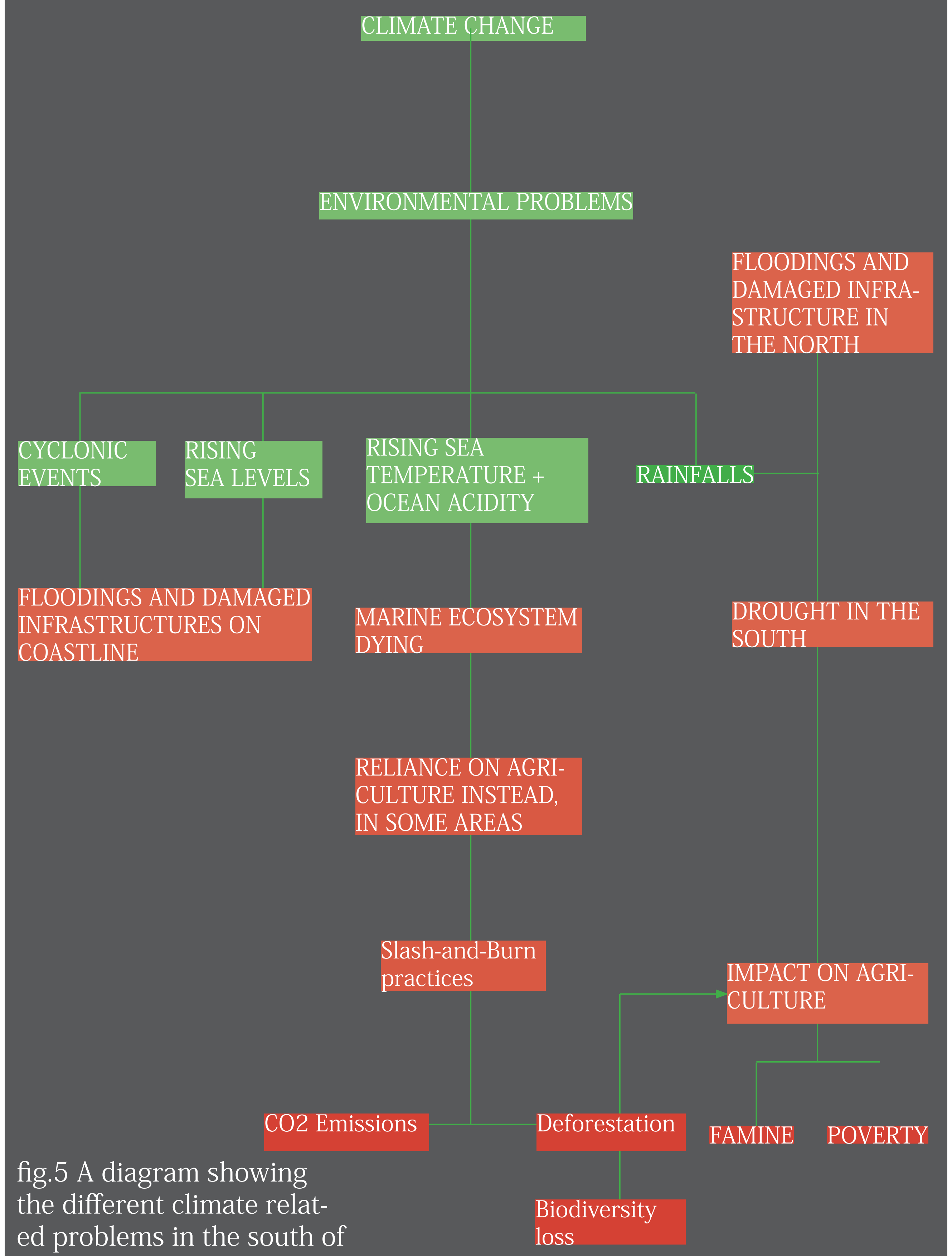


fig.5 A diagram showing the different climate related problems in the south of Madagascar.
S.Ramaherison (2022)

Whilst all problems should be tackled at some point, I chose to research on solutions around the least explored area of study, as we cannot solve every problem at the same time : **Ocean Acidification** (OA).

Ocean acidification refers to a reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO2) from the atmosphere. Absorption of carbon dioxide by the ocean is causing a lowering of the ocean's pH, which means that the ocean's chemistry is changing.

Pre-Industrialisation pH value of the Ocean water 8.179 Current pH value of Ocean water 8.069 (increase of 28.8% in the H+ unions since the industrialization of the 18th century)

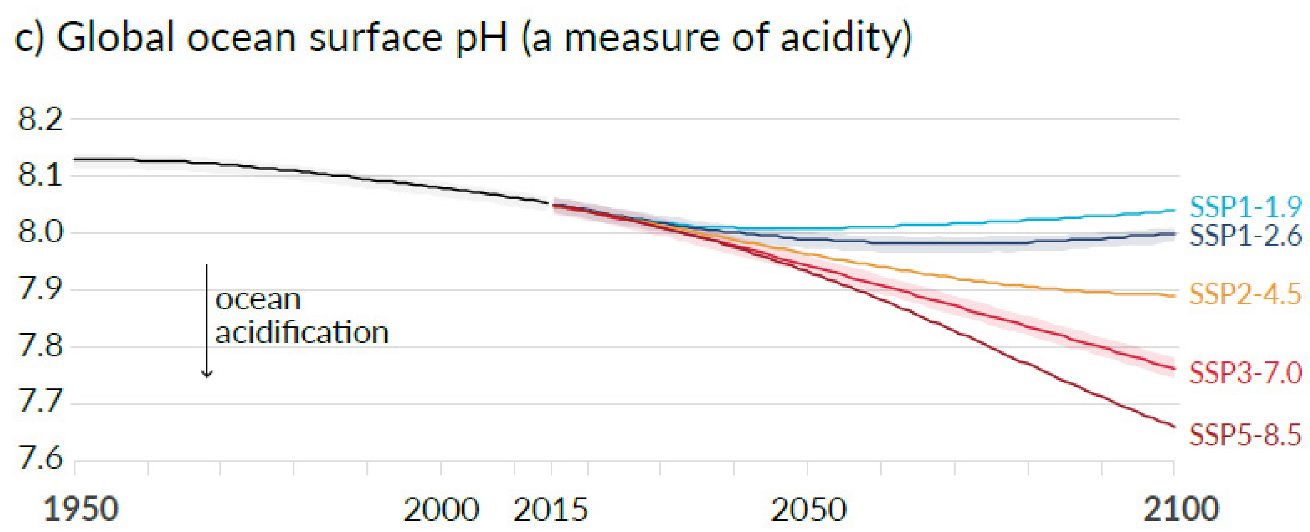


fig.5 Global ocean surface ph's evolution and prediction,

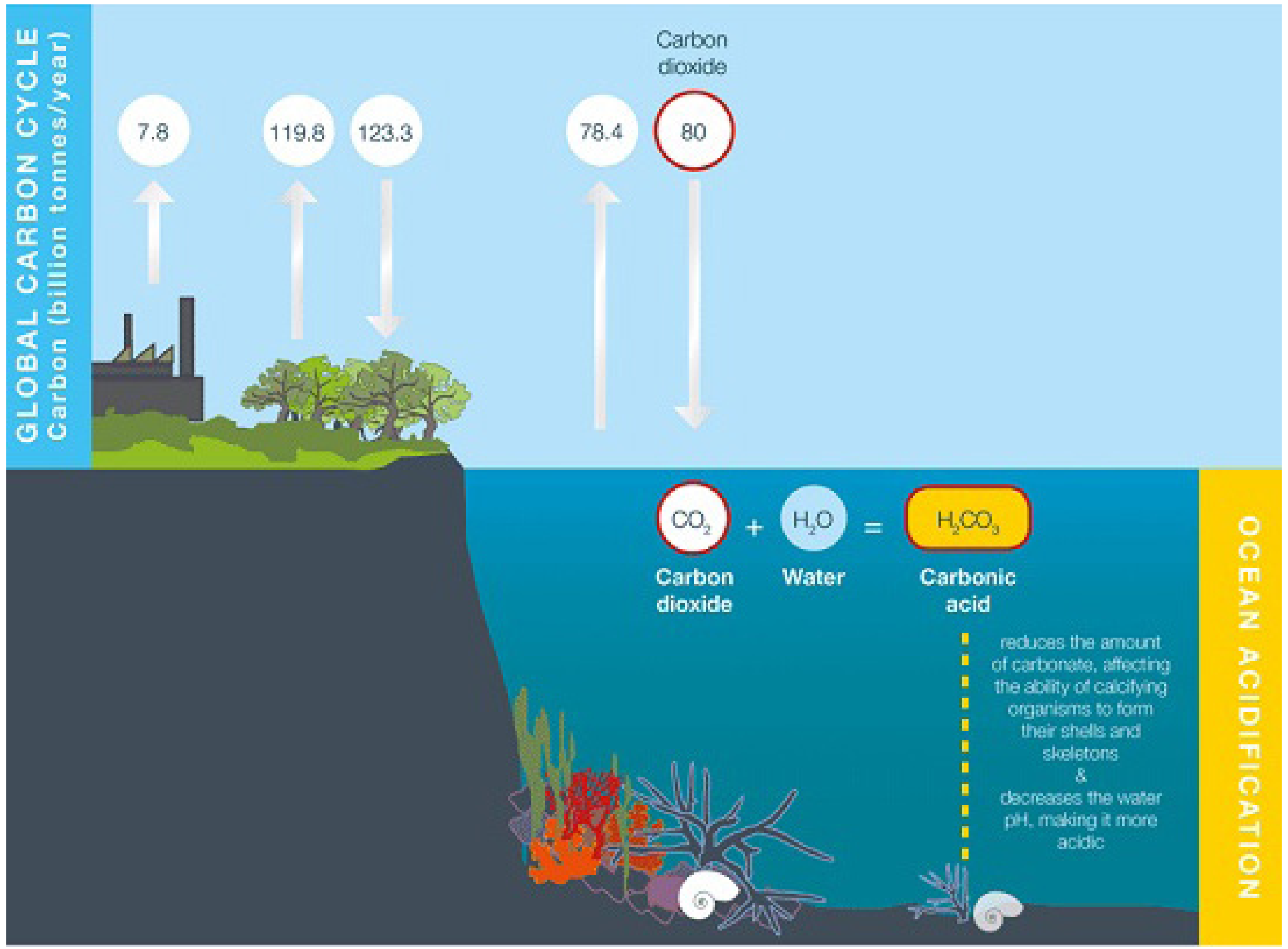


fig.6 Ocean acidification schema, Smithsonian Ocean, https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification, 2022

Considered the “evil twin of climate change”, its effects are still mostly impacting marine life - not humans. However, communities relying on the fish industry are already seeing the negative impacts, as we can see in Madagascar or other vulnerable countries (coupled with coral bleaching, an effect of global warming). A 2016 study found shorter term impacts in tide pools. The study by Kwiatkowski, et.al. found that ocean acidification can affect marine life in tide pools, especially at night. (picture of tide pools). As I researched the problem and what my role as a designer could be in this global issue, I started researching specific places where it’s happening, but as I stated before, the research field is still at an early stage (from a scientific and ecological point of view) so researchers cannot find specific places where OA is happening yet.

“The research field still isn’t at a stage where it can identify specific places where ocean acidification is having greater effects, as research is either monitoring of oceanic pH levels from ships, or laboratory based experimental work.”
– Nova MIeszkowska, Senior Lecturer, University of Liverpool Marine Biological Association Research Fellow

2. Designer’s role

2.1 The root of the problem

Now, what really is causing this global chemistry imbalance ? How could we possibly stop the industry from harming even more the planet ? How can we, as individuals act against these practices ? Where is the problem coming from and how can we possibly solve this issue ? Is it even solvable ?

If we start looking at the root of the problem, we have to fully come back to the essence of these CO2 emissions : consumerism. Even if we could even see parts of the worlds impacted by this global issue, at an individual scale, wouldn't the best way to solve the problem would be to stop our own CO2 emissions ? As we cannot really stop industries from emitting CO2 from an individual point of view, we as people have to take the lead to almost act as lobbyists, act as the changemakers to stop these CO2 emissions.

We have to shift from fossil fuel products production to more sustainable practices. As the root of the problem is fundamentally the industry, the other actor in this complex problem is the consumer, or "us", the "developed" part of the world. A recurrent phrase says that the developed world is responsible for problems impacting communities who have a so small amount of CO2 emissions compared to the rest of the world, they are just suffering from things they are not responsible for.

We can see the differences in CO2 emissions in Oxfam's diagram (fig.7, next page), where the richest 10% are responsible for 49% of CO2 emissions, while the poorest 50% are responsible for less than 10% of these CO2 emissions.

So as part of the 40% "middle class" population, responsible for 41%, what could we do and what would be our role?

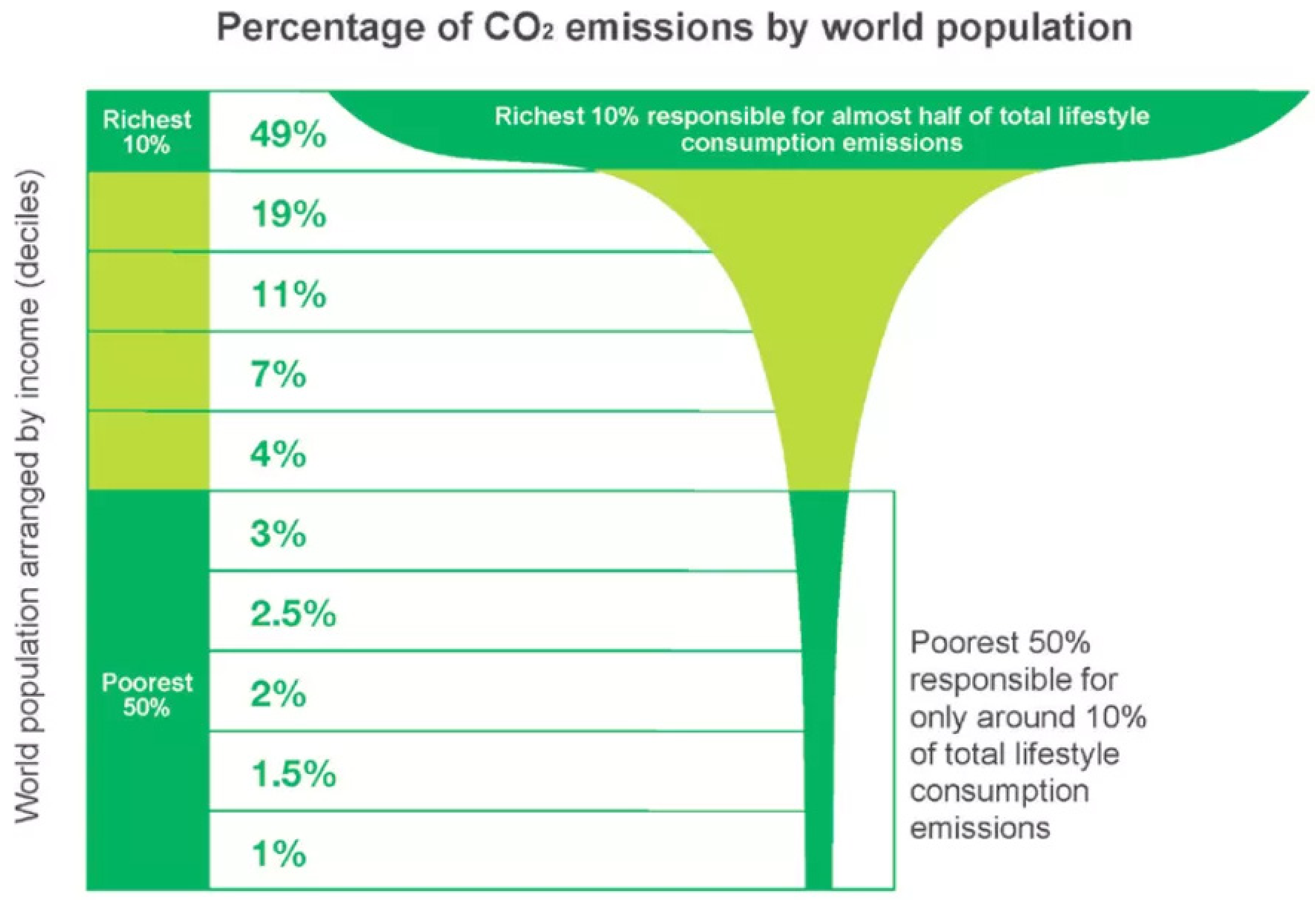


fig.7 Global income deciles and associated lifestyle consumption emissions (Oxfam, 2015)

2.2 The different solutions

I stated earlier “is it even solvable ?”. A problem that large and global can’t be solved by only one solution, therefore innovators, scientists, designers and engineers around the world have to put their efforts together to solve or at least prevent the problem from worsening.

So far, there are not a lot of solutions emerging, since a lot of research centres are still at the stage of understanding OA, using artificial devices replicating oceanic conditions, called mesocosms.

We can already count some of these different natural solutions, proposed by different scientific researches :

- The OCEAN NETs aka Negative Emissions Technologies (GeoMar) which include :

o Fe/N&P fertilization (fig.14)
o Terrestrial biomass dumping
o Macroalgae farms
o Seagrass (fig.9)
o Mangroves (fig.8)
o Marine biomass for Biochar (fig.12)
o Artificial downwelling and Artificial upwelling
o CCS – Carbon Capture and Storage (factories along coastlines, need huge investments)

- Chemical weathering through natural minerals to alkalinize the oceans (fig.11 and 15)

- Algae bioreactors (similar to Carbon Capture Storage facilities, but with algae, sequestering carbon in algae this time) (fig.13)


fig.8

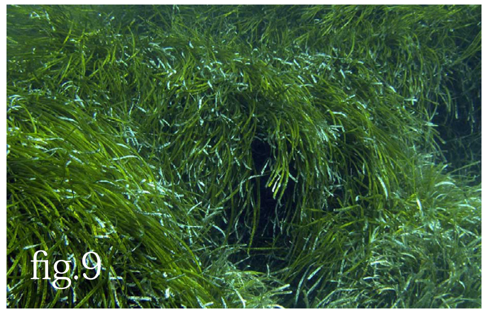


fig.9


fig.10


fig.11


fig.12

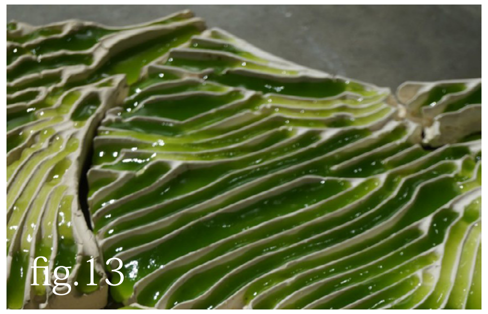


fig.13


fig.14


fig.15

But what stops us from using these solutions already to tackle the problems mentioned above ?

The first aspect of environmental solving facilities or innovations, to be installed and used, they need funding, space, and often need trust from governments or local councils. Secondly, these are just one part of the solution, they are what we could call mitigating solutions, but these cannot solve the problems oceans are facing alone.

The biggest game changer would be, in fact, the reduction of anthropogenic emissions, which means cutting down on plastic production, fossil fuels use for transportation, slowing down intensive agricultural practices, stopping coal mining, replacing CO2 emitting construction materials, etc.

All of these are linked to individual consumer behaviour, policymaking, and industry practices.
Therefore, my role as a designer would not be to engineer new Carbon Capture facilities or other expensive devices to mitigate OA, but educate people

How can we empower people in the deacidification of the oceans through waste-consumer behaviour ?

2.3 Objects of the ocean

The aim of the project now has shifted from a product design problem solving only perspective to a behavioural project, through the use of industrial design methods.

We now know that the problem cannot be solved solely through devices and facilities, and the main problem is still our overuse of resources caused by a consumerist society. As it will take time for people's behaviours and habits to change, especially in society where comfort through consumption has been established for decades, what if start by communicating about the problem now to prevent it to worsen in the future ?

A way to do that would be through the redesign of harmful objects used around the seashores, as familiar artefacts for people or "users". The aim would be then to replace these harmful materials into beneficial materials – such as the natural materials used as NETs above – to not only cut down the production of plastics on one object, but would partially help seashores ecosystems, if these are left around the coastlines.

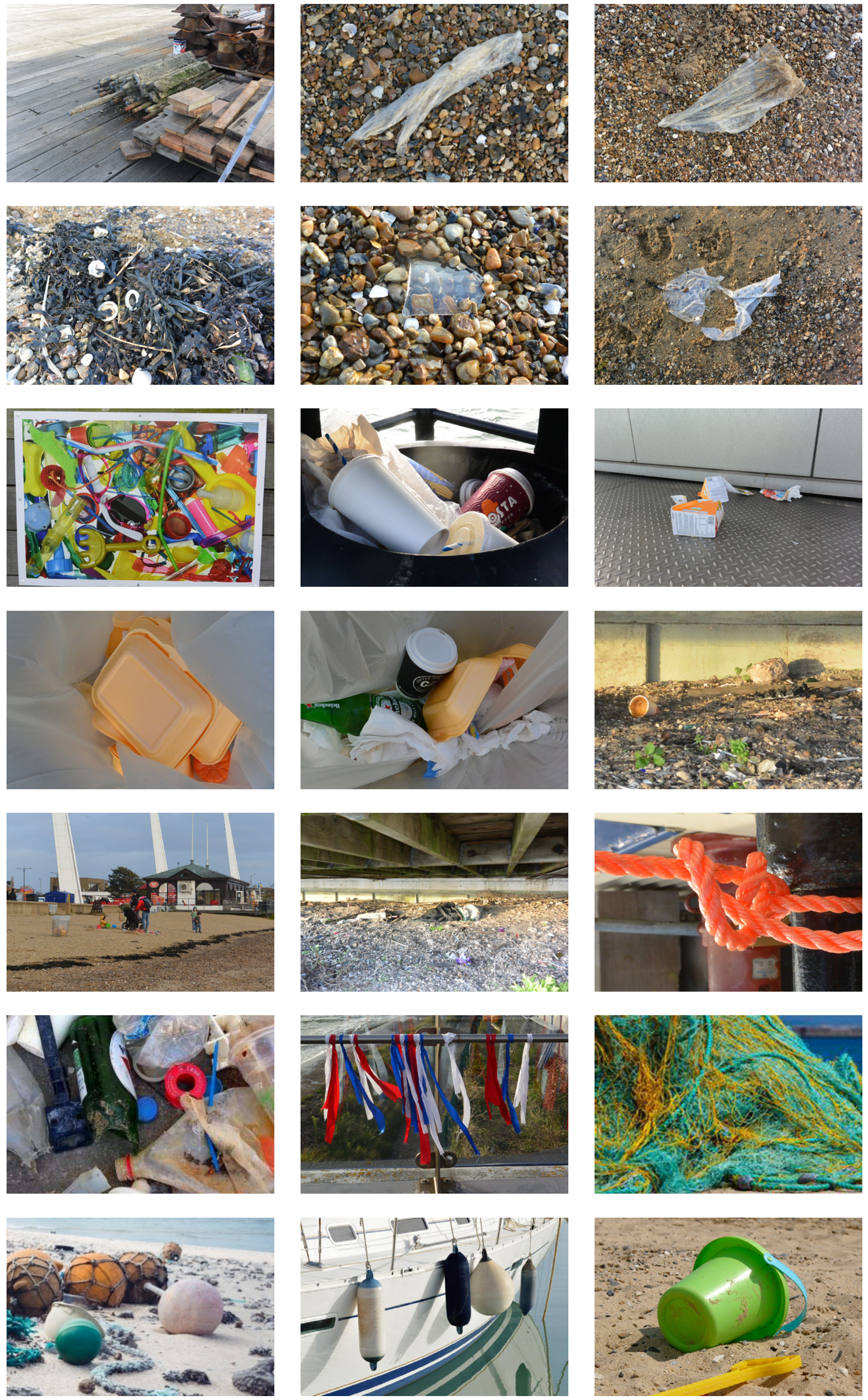
What would be these objects ?

After observing Southend's popular beach on a Sunday afternoon, I took notes on what is left accidentally (or not) by people around the seashores, what is used around seashores and what would be potentially harmful to the ecosystem :

Plastic Buoys
Floaters
Fish and chips shops packaging
Ice cream cups
Coffee cups
Plastic bottles and caps
Buckets and spades
Fishing nets
Synthetic Rugs
Plastic bags

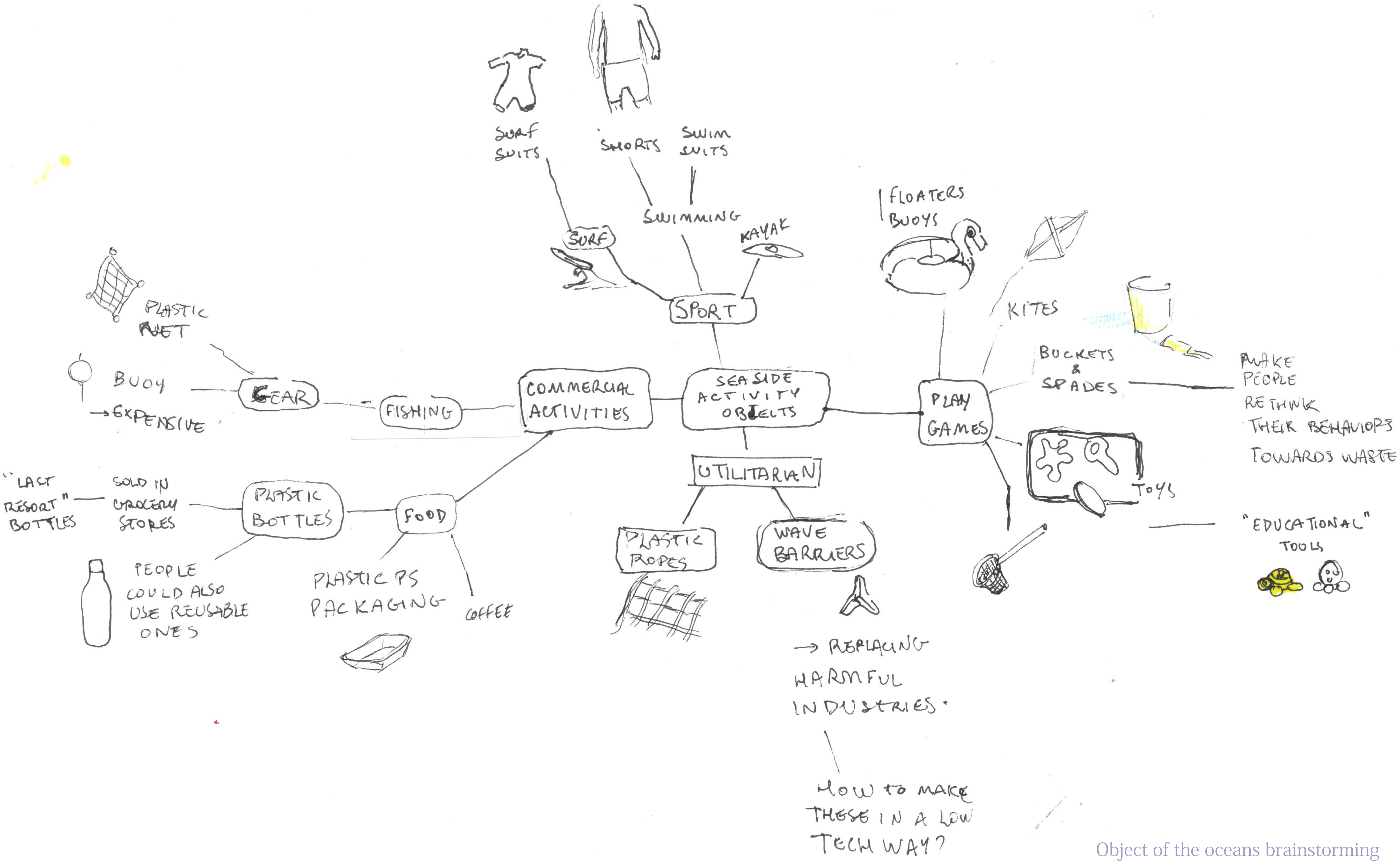
Ocean and coastal farming can be a source of marine litter in the form of aquaculture equipment and plastics, including **ropes, buoys, mesh bags, anti-predator netting, cages, tanks,** etc. This equipment may be damaged or discarded leading to marine litter which is often concentrated in coastal areas where aquaculture is practiced.

Expanded polystyrene is the leading form of marine litter from ocean and coastal aquaculture activities, but there are currently no global estimates for the amounts of marine plastic litter generated from this sector.

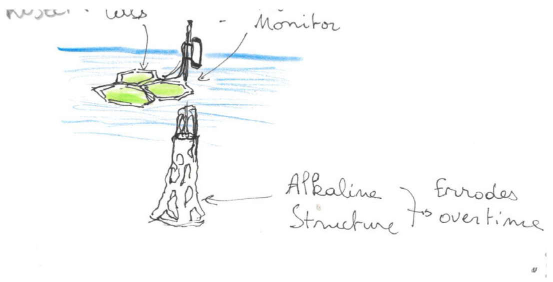


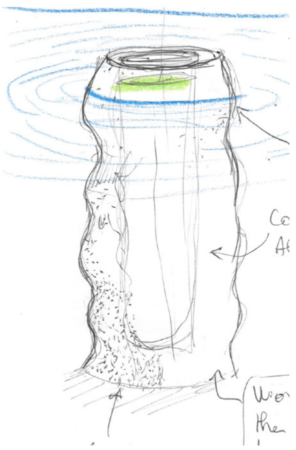
3.1 Ideation

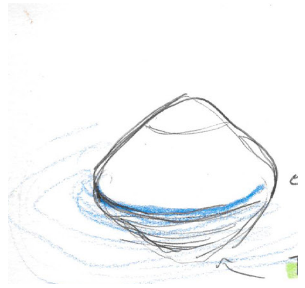
After analysing and observing people's behaviours around the beach, marine litter, and harmful materials for marine ecosystems, I started exploring concepts around replacements for these harmful materials, into beneficial materials : oyster shells (Calcium Carbonate), Olivine and Alginate. But still opening my ideas to other biotechnologies potentially beneficial to the marine ecosystem.

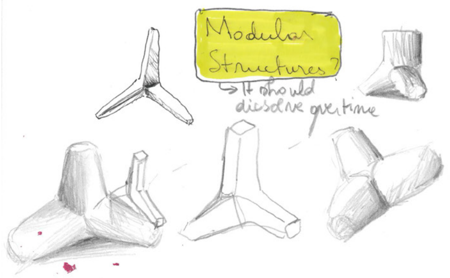


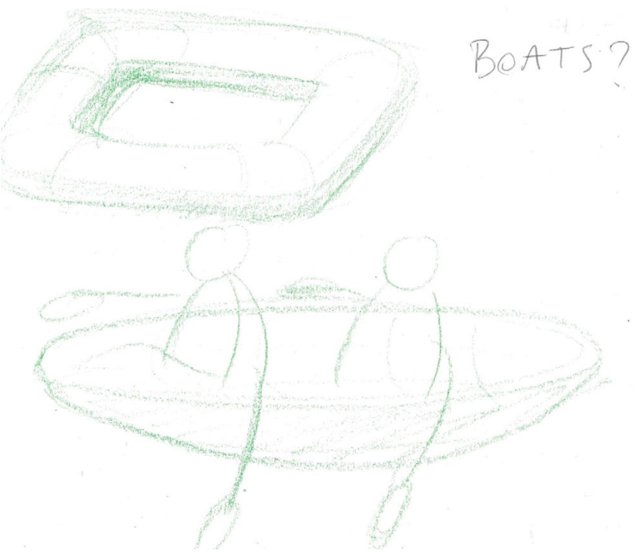
Object of the oceans brainstorming



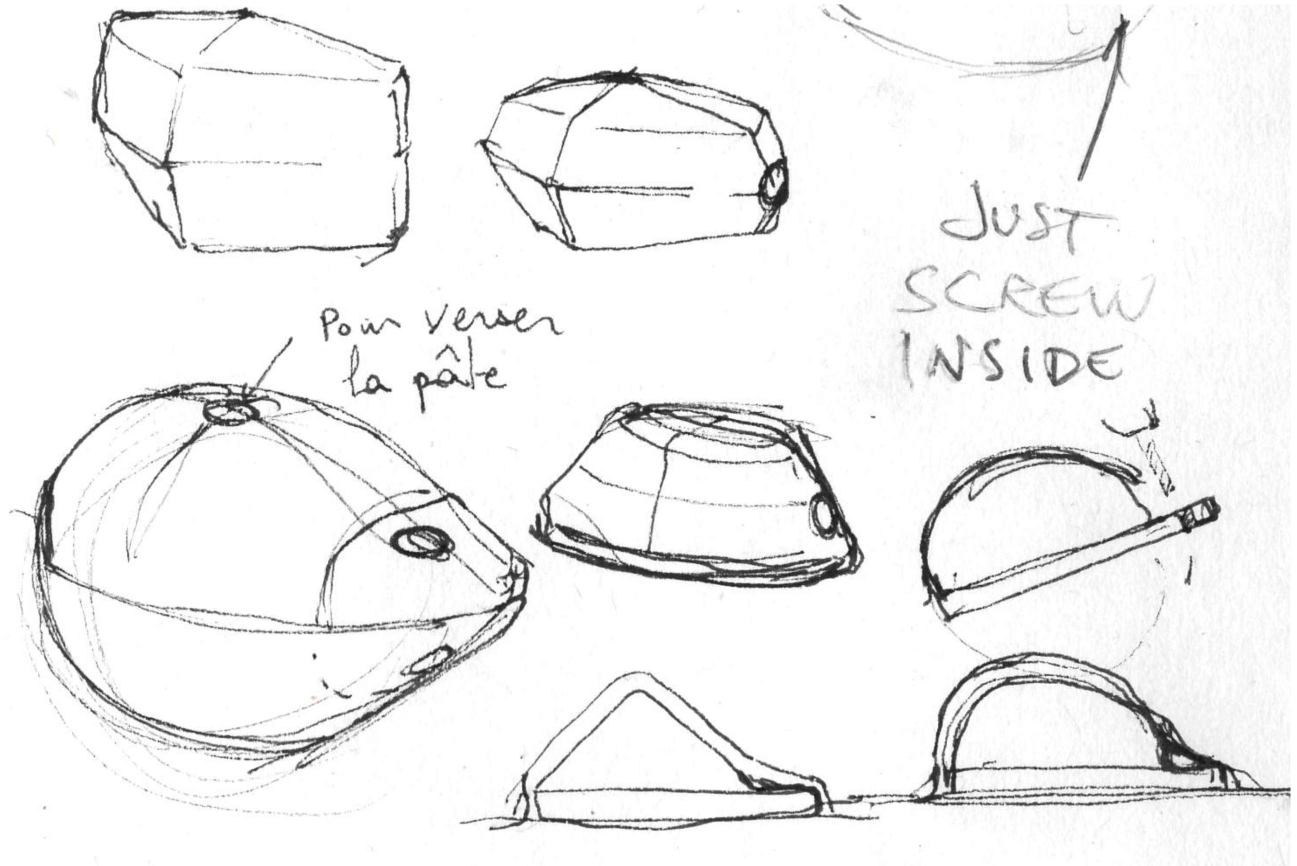


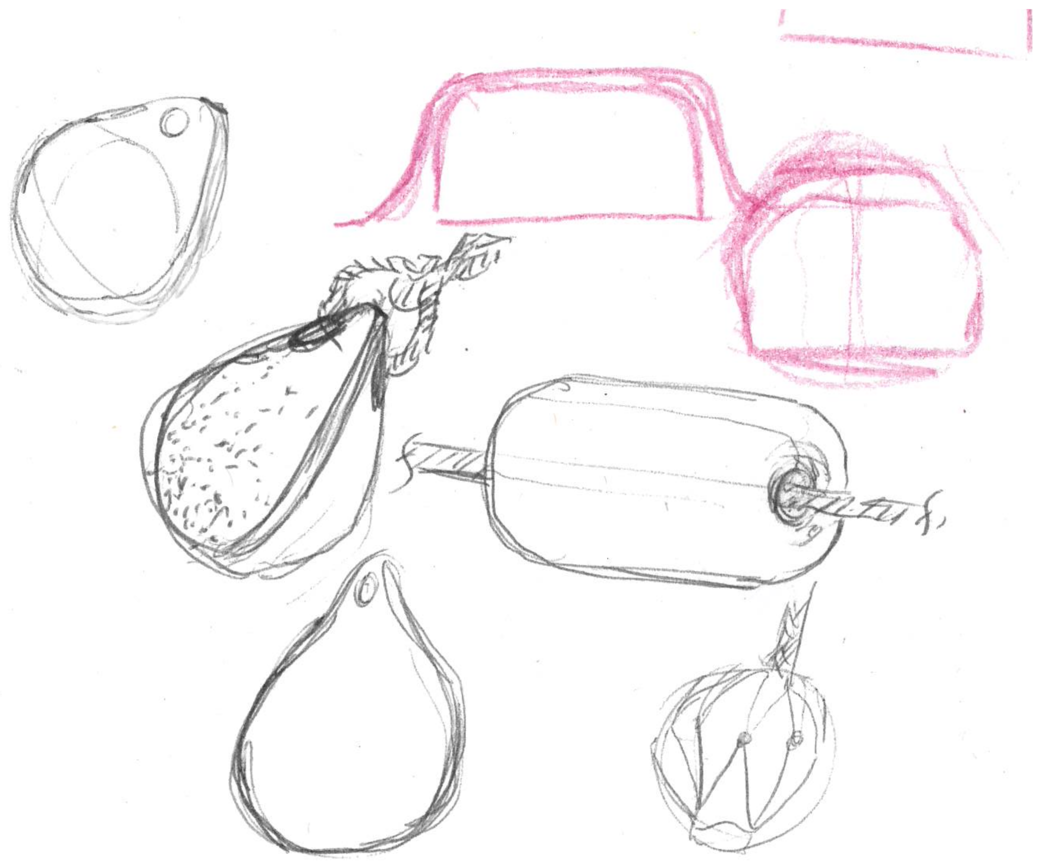






Initially, my aim was to not give too much responsibility to the users to facilitate the use of these sustainable products by the use of a deacidifying buoy. The buoy not working as planned (though stabilising the water's ph), I shifted from it to design other objects.





Buoy prototype

Different scenarii were possible :

1. should we not inform the user about the material composition, but letting them make "the mistake" of leaving the object unattended on the beach, thus acting as a sustainable activist without knowing it ?

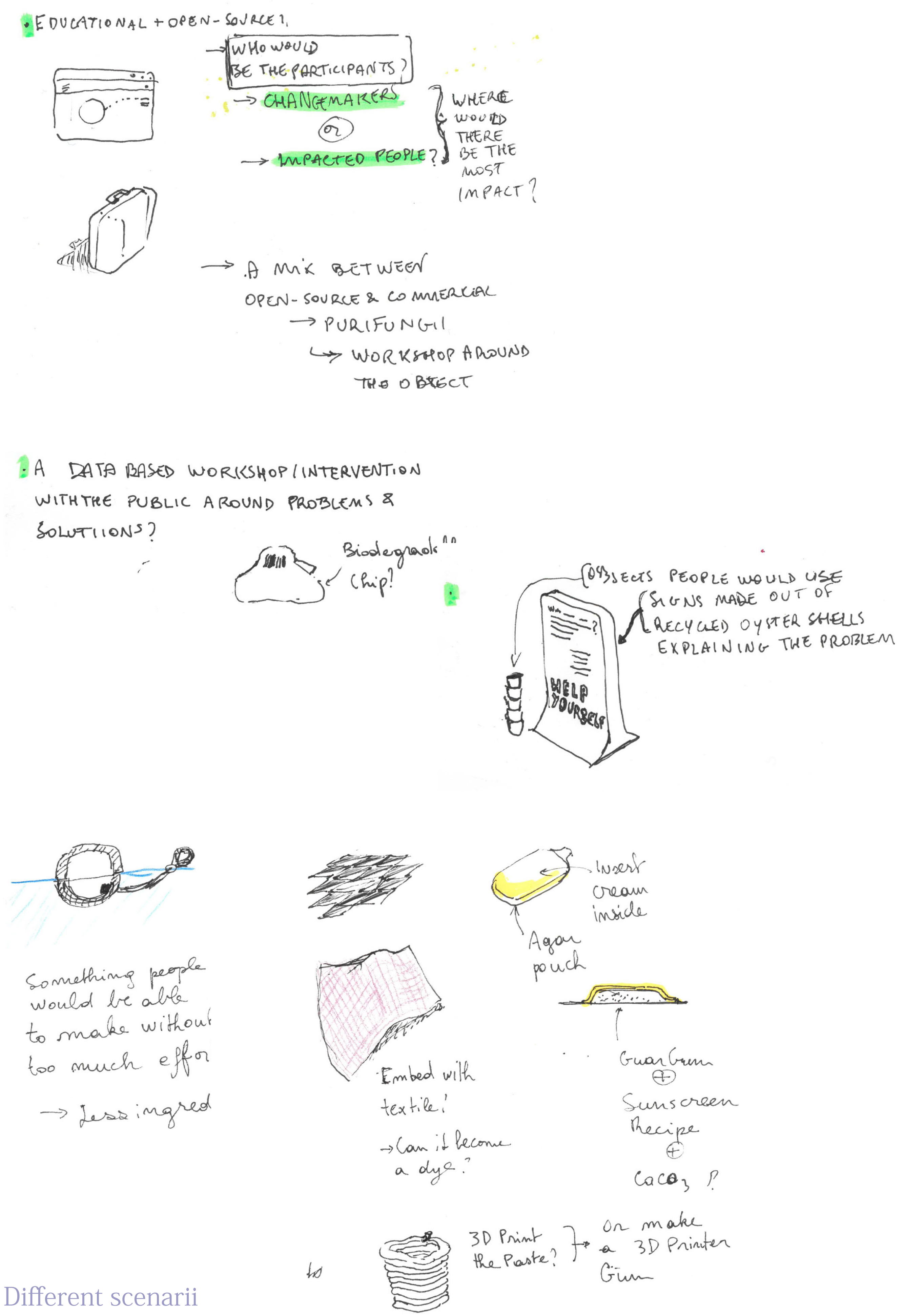
2. should we inform the users on the material composition through events or workshops, making them aware that the object is in fact beneficial to the ocean ?

3. the last way of making this object would have been to inform them about the beneficial aspects, and giving them the responsibility to throw the object on the seashore by themselves.

Giving them an object informing them about the issue of OA and the potential and current solutions at the same time would impact their behaviours probably a lot more.

Now, what object would have the most significant impact, and relevancy ?

Buckets and spades, packaging, and coffee cups and ice cream cups are the most found objects when it comes to marine litter around the seashores : takeaway packaging account for **6% of plastic items on seashores, ranking at number 4 in plastic items on seashores according to a report by Earth's Watch UK.** The number 1 are plastic bottles, however, these are easily replaceable today by reusable bottles, which are more and more popular nowadays.



Different scenarii explored

Out of these objects, the takeaway packaging would then make more sense than the others as it is the most difficult to replace in terms of scenario design : takeaways will still use takeaway packaging for a long time, so we must find a way to replace the harmful materials used to design these takeaway packagings.

In conclusion, three issues are tackled through this simple object redesign :

- **reduction of harmful marine litter**
- **cutting down the production of plastic packagings**
- **partial mitigation of OA through mineral weathering (through the use of Oyster shells as core material)**

3.2 Material Design

To achieve the design of this new takeaway packaging, I explored different materials used in chemical weathering first :

Quicklime

acts as a alkaline mineral, but extremely energy intensive to produce, and might warm waters , which could harm the ecosystem if used at a large scale.

Olivine sand

acts as a alkaline mineral, found around volcanic places, and sequesters CO_2 when reacting to water. The only drawback is that it needs to be extracted from mines to be used, but at least the CO_2 emitted from the extraction is negated by the use of olivine itself (CO_2 sequestration by olivine > CO_2 emitted from olivine mining)

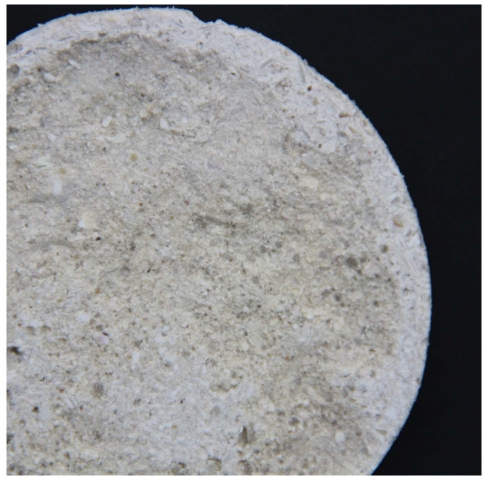
Calcium carbonate

acts as a buffer in seawaters by sticking ions to CaCo3 particles, found in most marine species and seashells. The interesting part is that it is also found in Oyster shells and mussel shells, which means that it could be taken from Oyster farms or producers, not needing to mine anything, which makes the process circular and sustainable.

Chitosan was also used as a binder at some point which makes the material much more resistant, but the list of ingredients to make the packaging out of it is longer than the recipe with alginate. The first recipe uses less external ingredients, or processed ingredients while the second one is a bit more complex. Therefore the first one is the easiest to scale up.

Alginate binder + oyster shells

- Hard - mineral like material
- Neutralizes acidity
- White - green/Blueish when hard
- Soft, weaker when wet
- Water resistant to some extent : it can float for at least 10 whole days if no one touches it
- Breakable



Chitosan + Oyster binder- Hard - mineral like material, looks a lot more natural than with alginate

- Looks like cement
- Neutralizes acidity
- Water resistant : dissolves aftera approximately 10 days
- Breakable but probably stronger than the one with alginate
- A bit flexible

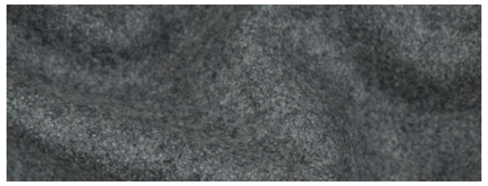
Potential new natural binders from the sea (other than alginate)

Carageenan

> natural ingredients that are extracted from red edible seaweeds

> An additive used to thicken, emulsify, and preserve foods and drinks.

> so far the best alternative to alginate



Seawool
Recycled PET mixed with oyster shells

Not biodegradable, but could be taken from beach waste...

Agar-agar

> Natural seaweed binder used primarily in patisseries to replace animal gelatin

> Too fragile to be used as a replacement for bioplastic packaging

Other potential biobased binders (not from the sea)

Plantain
Xanthan gum
Shellac (potentially not biodegradable)
Candeilla
Guar gum
Arabic gum
Sugar
Bagasse
Bees wax

1. Seawater 4ml
7.01

2. Seawater + Calcium carbonate*
7.48

3. Seawater + Eggshells
9.31

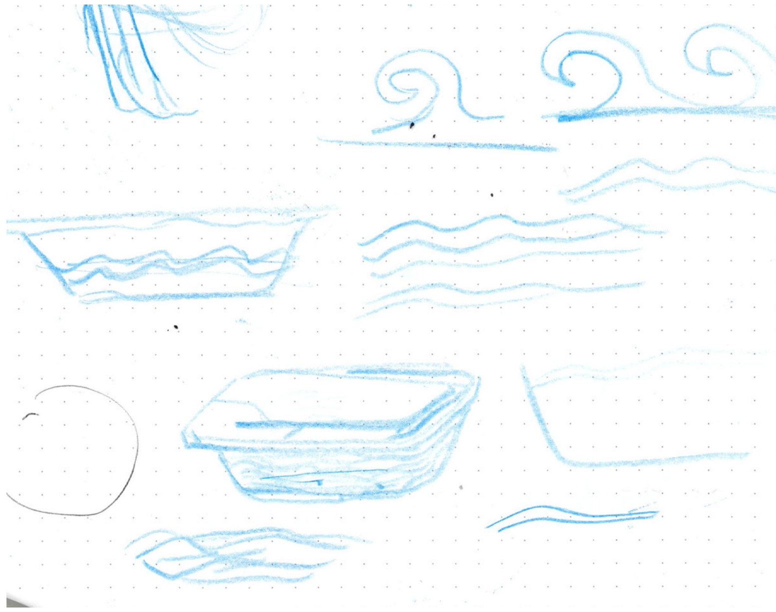
4. Seawater 4ml +
Sodium hydroxide
13.59

3.3 Prototyping

Recipes (for one packaging each):

Alginate oyster shell composite :
10 teaspoons of Crushed Oyster shells, 2 Teaspoons of Olivine sand 13 Teaspoons of Sodium Alginate, 200 ml Water

First attempt to prototype from the Thermoplastic



Final design

Inscription on the packag-
ing :
“Help marine ecosystems by
leaving this for the sea”

4. Democratizing science through design
4.1Asymbolic object
4.2 Familiar symbols to incentivize
4.3 Behavioural change and people’s

4.1 A symbolic object

A key aspect of this project is the communication of the issue through the artefacts and events around the objects made for it. Through these events, I as a designer will act as a knowledge facilitator as I don't have the pretention to be as knowledgeable as a Doctorate working on the issue, the designer here acts as the bridge between science and the general public.

How can we summarize an issue so complex and invisible to the eye ? How can we bring the public to even get interest in issues related to an ecosystem which is not theirs (oceans, as I mentioned before are the least explored subjects in ecology when compared to terrestrial ecosystems). By giving people an object they already use in their life, they relate directly to the scenario and use of this object, the different significances the object has, which is here waste, production, plastic (or fossil fuel materials) and consumerism. When using this packaging, people are also interested in what makes it different from the traditional packaging, thus making it also an object of interaction, giving me the opportunity to explain the issue, and the benefits of the material.

If the 7.87 Billion people on Earth started using this packaging as much as people use traditional polystyrene packaging, we could probably act as a giant deacidifying facility all around the world.

4.2 Familiar symbols to incentivize

Now, how can we trigger people's behaviours through a practical object, whilst communicating a problem at the same time ? How design can shift people's current behaviours into new ways of thinking and doing ?

This project is tackling a throw-waste problem, which will be the first idea people will have in mind when seeing it, but there are actually multiple layers to the idea, so the object has to communicate both the issue of OA and the solution scientists and engineers are proposing (which I am re interpreting through this object).

Examples of sustainable products to create awareness about ecological issues :

"This sweatshirt is colored with an environmentally friendly dye, created using a recycled water system. The fabric is made from 100% organic cotton." – PANGAIA

"finally a box that is truly MADE TO BIODEGRADE" – NOTPLA Packaging

"Hey! I use a seaweed coating instead of plastic, and will degrade naturally… like a piece of fruit!"
- NOTPLA Packaging

These approaches to describe material compositions and the problem behind the idea are good examples of synthetic ways to explain complex material sciences to the general public. However, both brands lack explanation on global issues they are tackling. The main element is the material composition, and what differs from regular unsustainable materials.

But the challenge in the design of this product is the integrate both a solution, and an larger and more complex issue than the most common "plastic" or "unsustainable material" issue.

One of the best example of incentive through symbols in daily products from the last decades is the universal recycling symbol, a symbol created during for a contest celebrating the very first Earth day in 1970 by Gary Anderson, then a 23-year-old college student at the University of Southern California. This symbol was inspired by various different symbols : Volkswagen's then recycling symbol for automobile parts, and the Möbius strip. These blends of symbols make the pictogram easily identifiable to the general public, while remaining simple.

This symbol alone, without any written description (most of time), incentivize people to recycle the stamped products by themselves, without having to think too much about the whole context and story of the product.
But symbolism isn't the only way to lead to positive change in people's behaviours, it is, in fact just part of a whole ecosystem of incentives to create a positive change to a broader problem.

4.3 Behavioural change and people's reactions

As a person who grew up in the 21st century, one of the few things I remember about my education is how we were taught very early at school about sustainability and global ecological problems. At the age of 10, in primary school we were already taught about some of the problems oceans face and the future of oceans if we didn't start to act to create positive change. We could see on TV announcements or programs talking about the new recycling rules and pictograms. We can see that just by a global communication about these recycling rules and laws, pictograms, and environmental problems through media, people unconsciously become used to them, therefore becoming part of the solution to a global problem.

However, this project takes a new approach to these rules surrounding waste.
The project emphasises people's negative behaviours towards beach waste by telling them that leaving waste in the natural environment can potentially save the seas with these new materials.

Surprisingly enough, when the project was shown, people didn't question the fact that the product is supposed to be left in the natural environment. From the "specialists" point of view, we can advance that people seem to follow what specialists about the issues talked about tell them. But some people were still sceptical about whether this product is truly beneficial to the seas, even when all the ingredients required to make it are directly shown to them.

Next steps

The next step for the project is to create another change in behaviour towards waste management and environmental awareness, as shown in the various examples above, or how to communicate the new "ritual" of waste to the general public, through social media, events and other tools for spreading behavioural change.

From these previous "experiments" on behavioural change in people with waste management, specifically when it came to recycling, we can conclude that this change in tendency towards waste might raise awareness around the issue of Ocean Acidification and its solutions to some people (mostly the ones interested in environmental problems). However, the major part of the population will most probably just unconsciously change their behaviours towards waste without necessarily thinking about the global and more complex issue of Ocean Acidification, which is still a valuable part of the solution to tackle OA.

I would also like to explore further the potential of cyanobacteria as another agent for Oceanic CO2 sequestration in the future. However the research is still too early to use it as a way to realistically capture CO2 on a global scale, without harming the surrounding ecosystem.

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